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THE TEACHING OF DESCRIPTIVE ASTRONOMY.

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FOR POPULAR ASTRONOMY

Several facts have obtruded themselves upon the writer's notice in the course of an experience of fifteen years in teaching the elements of Descriptive Astronomy to classes composed of pupils many of whom had no real grip upon any mathematics beyond geometry.

In reply to a request from the editor of POPULAR ARTRONOMY we proceed to state some of the ideas which have been brought out by this experience.

It is presumed that no reader belongs to the number of teachers who are content to have such study confined to memorizing and subsequently reciting the leading facts about the heavenly bodies, or who wish it to contain the minimum of mental gymnastic. On the other hand it is clearly borne in mind that the mathematical portion of the subject must, for practical reasons, be confined within very narrow limits.

1. The first point to be made is that as original, independent observations constitute the ground-work of astronomical knowledge, so the scholars must be imbued at the outset with the idea that they must confront the sky repeatedly, in order to attain a satisfactory knowledge of the subject. They should fix in mind the more notable configurations of the fixed stars, become familiar with their changes of position with reference to the horizon from hour to hour, and from month to month, and should use this knowledge as a basis for understanding the real and apparent motions of the Sun, Moon and planets.

It is best to encourage each student to observe alone, having no one else present to make suggestions or to bias his judgment by expressing opinions as to the magnitudes or colors, or distances apart (in degrees) of the objects under observation. It is not wise to debar scholars from the privilege of occasionally working together in groups of two or three: it will be found advantageous occasionally for the teacher to meet the entire class on a moonless night under the stars, to remove difficulties, and to call attention to neglected matters. But the teacher should in-

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sist on a very large amount of independent work on the part of each pupil, and should not at first criticise reasonable errors in estimating magnitudes and distances. The class may be to d that the apparent magnitudes vary with the meteorological conditions, and should not be expected on any given night to conform rigorously to the accurate values given by astronomers.

2. It is well to begin the study without books, so that the students will not be in easy possession of an author's ideas, which they can assimilate and copy, without exercising much originality. Since everybody knows the Great Dipper, the teacher may first draw upon the blackboard a pretty accurate picture of the Great Bear, giving the magnitude of each bright star, and pointing out the place in the heavens where the constellation is to be found at the end of the evening twilight. Cassiopeia and Ursa Minor may be given at the same time, but the scholars should be required to estimate the magnitudes of some of the stars in these groups, and the distances between them, knowing that the Pointers are 5° apart, and that Polaris is 29° from the nearer Pointer. There may be assigned such work as counting the number of stars visible in the Dipper bowl, finding what star is reached by prolonging the line connecting two known ones, etc. The students may be asked to estimate the colors of some stars. The aim of these queries is to arouse interest, and to lead to independent work. Early in the evening a student may make a drawing containing Polaris, an imaginary vertical and horizontal line through it, and the Great Dipper. A similar drawing made late on the same evening will show the revolution of the star-sphere.

After such a start a teacher will find no difficulty in teaching the outlines of the principal constellations, and the apparent daily motions of stars in various quarters of the sky. If the streets run toward the cardinal points of the compass, it will be easy to have the scholars estimate the azimuths as well as the altitudes of certain bright stars at different hours of the evening. The writer is satisfied if a class learns simply the configuration of the chief stars of each constellation studied, so that they can reproduce it with fair accuracy on the blackboard at any time, or be sure of it, when facing the sky. The names of only the bright or otherwise interesting stars are learned.

3. Along with constellation-study should go the cultivation of the geometric imagination. The power of making mental pictures of geometrical figures in space is very little exercised by the average student. A little experimentation in this line will convince the most skeptical teacher. A few days since the writer

asked a college class of a dozen, averaging over 20 years of age, to point at the north pole of the Earth. It was carefully stated that the desired point was on the surface of the Earth, and the class were allowed nearly half a minute to think about it. At a given signal all pointed; all but one pointed *horizontally* northward; one pointed up into the sky. The writer then asked a young lady to point toward the Earth's centre. At first she pointed downward at an angle of about 45° with the vertical, but after several seconds of meditation she concluded that the centre was straight below her.

As soon as the students have grasped the idea that the celestial sphere appears to revolve about an axis drawn from the north celestial pole to the observer's eye, it will not be difficult to develop by suitable written questions (which they can study at home), the fact that the celestial equator is the trace on the sky of a plane through *the observer's eye*, perpendicular to the axis just mentioned, cutting the celestial sphere at the E. and W. points of the horizon, and running south of the zenith. Each pupil should make a mental picture of this as a line of light going across the sky, and may get its position fixed in mind by questions which require him to find out by observation whether certain stars lie north or south of it.

The position of the ecliptic among the stars may be roughly gotten by watching the Moon for a month: the positions of the equinoxes and solstices may be accurately determined by the aid of a map. The different systems of co-ordinates for the location of celestial objects will then offer no great difficulty, especially if the pupil is required to estimate at certain times the co-ordinates of well known stars.

The daily motion of the celestial sphere, as seen at the north pole or at a point on the equator can be readily impressed by a series of questions about the relative positions of the horizons at these places with respect to the terrestrial and celestial equators and the Earth's axis. It will be of great advantage to the class if they do not see a single book diagram explaining these matters, until they have thought them out for themselves. For scholars deficient in imaginative power, an orange, on which are marked the terrestrial poles and equator, and a visiting card which may be laid against the orange to represent the horizon of any particular place, will be helpful. The brighter students should be urged not to avail themselves of such aid, but to make a mental picture of a miniature earth in space, using an imaginary sheet of ivory as a movable horizon.

4. The work outlined above will be well in hand at the end of a month's time, in fair weather. Some observations of the Moon and the planets may also have been made. Books may then be placed in the hands of the class. The subjects of time and the seasons will be much clarified by actual observations of the times when the Sun and known stars are on the meridian, rise and set. By observations of the shadow of a building at noon the changes in the meridian altitude of the Sun from week to week will be noticed.

The work of observation is by no means to be cut off at the advent of the text-book; it should continue through the period of time allotted to the study. It may be extended to rude observations of variable stars, and to observations of occultations, eclipses, etc., especially if a small telescope is available. Opera-glasses and spy-glasses may well be employed continually upon the Moon, planets, Milky Way, wide double-stars and bright nebulæ. For much of this work the latter pages of each issue of POPULAR ASTRONOMY will be found helpful.

5. It is not difficult to make the optical principles of a telescope plain by experimenting with the different parts of a spy-glass, with combinations of pocket magnifiers, and with a cheap camera. Some of these experiments can be made upon the Sun, and some upon terrestrial objects. It is practicable for the students to perform many of these experiments without the teacher's aid, judicious questions being given, to which answers are found by the experimentation. Where a class has not frequent access to an equatorial or small transit instrument, the fundamental principles of these instruments can be fairly explained by a pair of shears. In the case of an equatorial one blade represents the polar axis, the other the telescope, and the screw-rivet uniting them the declination axis. Equipped with a pair of scissors the student is prepared to answer correctly a set of queries about the equatorial, which will lead him to a good understanding of the principles of the instrument. Some bright pupil may construct a model of an English equatorial, similar to the "star-finder" described by Professor W. A. Rogers some years since in the *Sidereal Messenger*. The use of this will materially assist in fixing the conception of right ascension, hour-angle, sidereal time, etc. If a student can have the use of an engineer's transit equipped with a Saegmuller solar, he should certainly get a good grasp of the principles of both a transit and an equatorial.

The editor of POPULAR ASTRONOMY will doubtless be glad if

any teacher of astronomy, especially in secondary schools, will write to him concerning points in his experience which may be useful to others. The study of this, the most ancient and the noblest of the physical sciences, has been much neglected in such schools, and even those schools which offer instruction in it do not usually attain any such measure of success as would flow from earnest enlightened effort.

UNIVERSITY OF DENVER, Sept. 30, 1896.

SKETCH OF THE ASTRONOMICAL WORK AT MUNICH.

G. W. MYERS.

FOR POPULAR ASTRONOMY.

In compliance with a request from the editor in a brief way to give a general idea of my course of study and of my surroundings during my two years' sojourn in Munich, the following is respectfully submitted.

The writer visited Professor Hugo Seeliger in the fall of 1894 and after learning from him the requirements and nature of the astronomical work contemplated for the coming year, was so favorably impressed with both the professor and the work that he determined to take up the study of astronomy at Munich for the ensuing semister at least. He accordingly passed the formalities of an examination for admission to the University at the opening of the winter semister of 1894-5 and had his name duly entered upon the roll of students. It may be a matter of interest to some to know that to one seeking admission to a German University, the entrance examination is a mere formality, provided the applicant carry a Bachelor's or Master's Degree from an American University, or the so-called *absolutorium*, or diploma of a German Gymnasium. To those not so qualified these formalities are in many cases a matter of more serious concern.

These ceremonies once passed, however, the applicant is entitled to visit as many lectures as he may choose, provided he gets the private consent of the lecturer and pay the lecture fees, though he may not hear less than two full lectures without the consent of the Rector of the University. A full lecture is a course of lectures running through the entire semister and comprising four or five lectures each week. The lecture fee is fixed by the faculty of the University and for those courses in which no ap-

paratus is needed the charge per semister at Munich is four marks for each hour in the week. When apparatus is required or where excursions to points remote from Munich are incident, the professor may make a higher charge and always high enough to cover any actual outlay on the professor's part.

If one become a candidate for the doctorate he must select a major and two related minor subjects. Students in astronomy at Munich usually select mathematics and physics for minors, as these two departments are specially strong here. This requirement as to minors is also a local matter. In Prussian universities, for example, it is necessary that every student, whatever his specialty, shall take philosophy as one of his minors, on the theory that it would be a manifest absurdity to confer the title of doctor of philosophy on any one wholly unfamiliar with philosophy. Through the influence of Professor Bayer, of chemistry, this relic of the middle ages was dropped a few years ago at Munich, to the universal satisfaction of all save the professors of philosophy.

The Royal Bavarian Observatory is beautifully situated on the highest spot of ground in the neighborhood of Munich, within the quiet little suburb of Bogenhausen, about twenty minutes walk from the university. The dwelling of the Director is in the same enclosure as is the Observatory and the observer and mechanician reside within the Observatory itself.

The officers in charge of the Observatory during the years 1894-5 were the following:

Professor H. Seeliger, Director; Dr. J. Bauschinger, Observer; Dr. Anding, Private Docent in the University; Mr. W. Liszt, Assistant; Mr. E. Esser, Mechanician; Mr. W. Villiger, Computer.

Early in 1896, Dr. Bauschinger was chosen to the superintendency of the Rechen Institute which issues the *Berliner Jahrbuch*, this office having been vacated by the death of Professor Tietjen the preceding June. His vacancy at Munich was filled by the appointment of Dr. K. Oertel, the present incumbent of the office. Dr. Oertel is now engaged on the unfinished work of his predecessor on the definitive determination of star places from observations made with the Repsold meridian circle and hopes to push the work speedily forward to an early close.

The equipment of the Observatory comprises an extensive library of astronomical, mathematical and physical books and periodicals; a new six-inch Repsold meridian circle, a twelve-inch Fraunhofer refractor which has been recently worked over and

modernized by the Repsolds, a Reichenbach meridian circle, a fine new photometer, a six-inch equatorial for students use, several Riefler clocks and a number of prismatic circles, sextants, chronometers, etc., for the use of students. The Bavarian Geodetic Survey has a fine alt azimuth instrument and a three-inch Bamberg broken transit which are always kept in the Observatory except when in use. Many of the better instruments of the Observatory, and at times any of them, are available for advanced students. Experienced observers and computers are always about the Observatory who are ever ready to render to students any assistance needed in their investigations.

Seminary work in astronomy was carried on continuously in connection with the work of the lecture room and Observatory. In the seminar, the work of the students was quite varied; sometimes a student was assigned a subject for investigation and report; sometimes he was to present to the seminar, a review and criticism on some question occupying the attention of astronomers at the time; occasionally he was asked to give a summarized statement of his work with the instruments of the Observatory when that work was of such character as to be of general interest. At the close of his paper or lecture or criticism which usually occupied from one half, to one and a half hours, the speaker was exposed to the merciless fire of cross question from any or all who might choose to take exception to his views or conclusions. At the close of the inquisition, the student usually felt that the presentation of a paper to the seminar and maintaining its dogmas was no easy task and came out of the fray with the resolution to do his best next time. In the writer's opinion, the effect on the participant of the work of a typical German seminar is to arouse his enthusiasm and to awaken his latent energies as no other work can.

Viewed from the standpoint of the professor, the seminar was valuable in enabling him to judge of the capacity of his students to take in and assimilate the subject matter of the lecture room; in short, to learn his men, while the student himself in this work became acquainted with his own powers and had an opportunity to train himself in the faculty of putting things effectively.

Inasmuch as the lectures given for astronomical students during my stay at Munich will give an idea of the nature and amount of such work generally offered at Munich, it may be well to add a few words concerning it.

During the school year of 1894-5, Professor Seeliger gave two courses of lectures, one on Absolute Perturbations and another

on Photometry. The former he followed in the summer by a course on modern methods in computing perturbations, reviewing and discussing the methods of Hamilton-Jacobi, Hansen and Gyldén. Dr. Baushinger gave a course on Spherical Astronomy, another on Least Squares, and a third on Use of Ephemerides, Leverrier's Solar Tables and kindred subjects and superintended the work on the instruments in the Observatory. Dr. Anding read on Dioptrics and later on Special Perturbations.

Professor Lindemann of Mathematics read on Definite Integrals, and later on Theory of Functions, Differential Equations and Professor von Lommel of Physics give a course on experimental physics for astronomical students.

In 1895-6, Professor Seeliger read on the Theory of the Potential and Figure of the Heavenly Bodies. Professor Lindemann gave a course on Elliptic Integrals and Professor Graetz on Maxwell's Theory of Electricity and Magnetism. Each of these professors carried on seminary work in their respective subjects and to all these seminars, astronomical students were eligible.

In this connection, I would not neglect to mention another opportunity the student possesses when studying with Professor Seeliger, *viz.*, the professor's willingness to have students call upon him privately at his home and to present to him any difficulties encountered in their research work. While the professor is an unusually busy man and very soon makes the shirking student understand he has no time to waste, yet for the earnest student's difficulties, he always has time to spare.

But of all the many influences surrounding the astronomical student, tending to awaken in him a desire to know his science, I would place that of Professor Seeliger in the lecture room as chief. He is in the prime of life, enjoys perfect health, is an unusually ready computer, and a clear, profound and eloquent lecturer. He seldom errs in either numerical or theoretical computation and when he does make a slip with the crayon in a long and complicated mathematical development, he finds it with astonishing quickness. In no single instance during upwards of the three semisters I was privileged to hear his lectures, did he find it necessary to postpone the explanation of a difficulty until the next day. His theory and practice was to remove the difficulty when first met.

And last but not least, he is full of enthusiasm himself and possesses in no common degree the ability to beget enthusiasm in others. Though the equipment of the Observatory and surroundings in the way of public libraries, reading rooms, etc. of the Uni-

versity and city of Munich are of the very highest rank, yet I am even disposed to say of Hugo Seeliger as was once said of our own Mark Hopkins, that he on one end of a log and a student on the other are a university.

UNIVERSITY OF ILLINOIS.

CHRONOLOGICAL NOTES—IV.

R. W. McFARLAND.

FOR POPULAR ASTRONOMY.

Old Style—New Style. The dates given in English histories before 1752, are old style. This remark applies to every writer whose works I have examined. There is no reason to suppose that others follow a different way. Macaulay has more dates than I find in any other author. He had "purposed to write the history of England from the accession of William and Mary, down to a time within the memory of men still living."

His dates are mostly comprised within a limit of five years on each side side of 1690. In the body of the history you will find in volume I, [I use the early edition, in which the usual volumes I and II are paged and bound together as volume I; and the third and fourth volumes, as volume II.]

Vol. I, p. 216, Friday, June 15, 1688.
" " " 349, Thursday, Nov. 1, "
" " " 353, Sunday, Nov. 11, "
" " " 378, Monday, Dec. 17, "
" " " 397, Monday, Feb. 4, 1688-9.

All these are old style, as well as all the rest.

In the foot-notes dates are given by the score; and as these notes generally refer to letters and documents passing to and from France, the dates are given in both styles;—the upper figures marking the old, and the lower figures, the new style. A specimen or two must suffice.

$$\text{Vol. I, p. 382, } \frac{\text{Dec. } 28}{\text{Jan. } 7}, 168\frac{8}{9}$$

$$\text{" " 388, Jan. } \frac{4}{14}, 168\frac{8}{9}$$

The first is read Dec. 28, 1688, old style; or Jan. 7, 1689, new style; and similarly for the other. France had adopted the Gregorian Calendar, England had not.

The only variation from the custom of the nations as above described, obtains in this country, and that to a very limited extent. The settlement at Jamestown, Virginia, was made May 13, 1607, old style; that at Plymouth was December 11, 1620, also old style.

In the State Library at Columbus, Ohio, is a very large collection of works on American history. I have examined nearly every book in that collection; and, with two exceptions all works examined, place the landing of the Pilgrims on December 11, 1620, some saying *old style*, and others saying nothing on the subject. Of these exceptions, one is H. C. Lodge's "Short History of the English Colonies." He gives the date December 21, 1620, and says nothing about the style. The other is Thwaite's "Epochs of American History." He says, "December 22, 1620;" —and this is neither old style or new; it is *wrong*. The landing was made on Monday, and in that year the 11th of December was Monday. Add the ten days difference and you have the 21st.

From the date of the change of style in 1582, the difference was ten days, all the way to midnight of February 28, 1700; after midnight, the difference was eleven days. The day following the 28th was, in England, February 29th, for in old style 1700 was a leap year; but in France it was a common year; and what the English called February 29th, the French called March 1st, and the difference then was eleven days; and so continued till midnight of February 28, 1800; since which the difference is twelve days.

The change of style in England was made 170 years after the adoption of new style by most of the Continental nations. [John Stuart Mill, in his Logic, speaking of this trait of the English character says, "England . . . . . generally the last to adopt whatever does not originate with herself."] When England changed, the difference was eleven days; and some American wiseacre added 11 to "everything," and made the landing of the Pilgrims December 22, erroneously. This is the probable explanation of the palpable blunder. Many years ago I was present at a celebration of "Forefathers' Day," as the landing has been called. It was at a seminary under the management of a celebrated New England lady. In the course of conversation, I called attention to the error in the date. She acknowlekged the mistake when I pointed it out; and then in after years, celebrated the event on the same day as before. Such examples might lead one to doubt whether John Bull can rightfully lay claim to all the obstinacy in the world.

In Holmes's "Annals of American History," published in 1813, we find:

"Monday, November 13, 1620
Wednesday, November 15, 1620
Sunday, December 10, 1620
Sunday, December 31, 1620."

All these are old style, but Holmes says nothing about it. The like course is pursued in Ramsay's History of the United States, (1789). In his life of Washington he says, "Washington was born on the 11th of February, 1731, old style," This is right. The year 1731 did not end till March 24th following. Twenty years afterward the parliament decreed that the year 1752, and *subsequent* years should begin January 1st, instead of March 25th, as had been the case for a thousand years and more. By pushing New Year's day back to January 1st, Ramsay's date becomes 1732, and the 11 extra days added to February 11th, gives the 22d—a day which many people celebrate gloriously in this country. Chief Justice Marshall followed the course pursued by all the rest. The same is true of Murray's "Annals of the American Colonies," (an English work published in 1824) and of Thompson's Dictionary of American History, (1812). The two dates which suffer are December 11 and February 11.

Is it a desirable thing to ransack all the writings of all the colonies and change all dates between 1607 and 1752? Whoever would undertake the job would find that all the labors of Hercules in comparison therewith were mere child's play.

But the absurdest thing of all was done three years ago, when some over-zealous, but ill-informed persons in Boston, petitioned Congress to declare that Columbus discovered America on October 21st not on the 12th, as all the world had hitherto believed and said. The foolish Congress passed the foolish bill. Of course no European country paid any attention to the act. The landing was widely celebrated in Europe on the 12th, as it should have been everywhere. In this country the act caused confusion. Some lame attempts were made, by spasms, so to say, the small boy had his fun not caring whether "school kept or not."

I was glad to see the dignified way in which the authorities of the Catholic church gave the act the "cold shoulder." The order is not now before me, so that I cannot give the exact language, but the substance of it was, that the parochial clergy might use their discretion in observing it or not, as circumstances might determine.

It would be a very loose construction of the constitution which would assign to Congress any power whatever in this matter.

That body is just as competent to amend the Lord's prayer, as it is to adjust points in chronology. A writer in the August *Forum* says, "So long as large and influential portions of educated America look upon Congress as a sort of Nazareth out of which no good thing can come, it is impossible to feel any confidence that Congress would deal more efficiently with so difficult a matter as a National University, than it does with more practical matters of ordinary business concern." "One business concern" was that of fixing the boundary between Ohio and Michigan. An act was passed requiring an impossible thing to be done. A like absurdity was committed by the legislatures of two of the American colonies, in establishing the eastern part of the celebrated "Mason and Dixon's Line."

When one goes to Congress or the State Legislatures for matters of science, he may fare as did the man who sheared the pig for wool.

The manifest intention of the reform of the Calendar,—not to say the very language itself,—was that it applied to the *future only*. And this intention has all along been followed by the level-headed men of all nations. It is to be hoped that intelligent men in this country will conform to the usage of civilized society in general. So much for Old Style and New.

NOTE.—A second topic which I had proposed to discuss in this number is adjourned to a future day.

PROFESSOR H. A. NEWTON.

Professor Hubert A. Newton of Yale University died in New Haven Aug. 30. He had suffered for years with a chronic internal trouble requiring repeated surgical operations of a grave character, but almost at the last he insisted on the performance of many of his college duties.

Not often has an hereditary and natal gift been manifested more clearly than in the life of Professor Newton, whose father, William Newton, built the Buffalo section of the Erie Canal, and whose mother, Lois (Butler) Newton, was famed for her mathematical powers among her neighbors in Sherburne, Chenango County, N. Y., where their son, the subject of this sketch, was born March 19, 1830. Both parents, who traced an ancestry of the richest Puritan blood back to the first settlers of Connecticut, had migrated from that state to Sherburne when many parts of central New York state were still a wilderness. In that township

they bought later a large farm, which still remains in the family. Ten children were born to them, seven sons and three daughters. Of the sons, one, Dr. Homer Newton, became a prominent specialist in diseases of the eye and ear in Brooklyn. A second, Albro, has accumulated a fortune in the lumber business at the same city; and two others, Isaac and Warren, have won honorable and exalted names at Norwich, N. Y., the one as a lawyer, the other as bank president. One of the sisters has passed a large part of her life as a missionary in India.

Professor Newton, as boy and youth, fitted for Yale at the schools of Sherburne, even then giving early promise of those mathematical tastes which were to fruit so richly in maturer years. He entered college at the early age of sixteen during the second term of freshman year in the class of 1850. In the college records he appears as a speaker at the junior exhibition of his class with "India" as his theme, and in the graduation list he won an "oration" stand though his name is not upon the list of commencement speakers. More significant of his gift was his winning of the first prize for the solution of mathematical problems. Classmates who were graduated with him in 1850 were the Rev. Leonard Woolsey Bacon, Professor Bonbright of Northwestern University, President Brush, of Upper Iowa University, Professor Easter, of Georgia University, Professor Kellogg (valedictorian) of the University of California, Professor Waring, of Columbian University, Washington, D. C., and Ellis H. Roberts. After graduation, for two and a half years, he studied higher mathematics at Sherburne and in New Haven, was appointed tutor at Yale in 1853, taking full charge of the department of mathematics during the illness of Professor Stanley, and two years later, his rare powers being then fully revealed, he was elected professor at the early age of twenty-five—probably the youngest graduate of the college whom her corporation has ever promoted to a full professorship.

After a year of study passed in Europe Professor Newton entered upon his work in the class room, joining with it much outside labor which appears to have been at first in the direction of the higher development of analytical geometry and calculus. In 1857 appeared his first published paper "On the Motion of the Gyroscope," which was printed in *The American Journal of Science*. But he soon entered, almost as a pioneer, that field of astronomical research which included the movements and laws of cometary and meteoric bodies. In 1833 Professor Dennison Olmsted of Yale had witnessed the wonderful meteoric shower of

November 13th in that year, and had expounded in a general way the hypothesis of cosmic origin and a fixed orbit for the November meteor stream. That theory Professor Newton took up, and by a series of the most careful and exhaustive computations along original lines proved five accurately fixed values for the revolutions of these periodical shooting stars, and next determined how their real orbit could be distinguished from the others. He thus was enabled to identify the meteoric shower with the comet of 1866, having a period of 33¼ years. These important demonstrations have been followed by many others in various branches of the same general subject. In 1864 he published a "memoir" on sporadic meteors, determined their number and frequency in the space traversed by the Earth, and showed that they had long orbits like comets. Almost every scientific phase of meteors, individual and collective, as well as of comets, has been treated in his exhaustive analyses, and out of fifty-six of his recorded publications up to 1893, no less than twenty-nine have related to those celestial bodies.

His labors in this branch of astronomy were not merely personal in their character and results, but gave an immense stimulus to the study of meteors and comets in this and other lands. Under his advice and supervision the Connecticut Academy of Arts and Sciences printed for circulation a map of the heavens on which the apparent paths of meteors could be marked down, and in this way a vast set of recorded observations was obtained in various parts of the country. With the comparatively recent application of stellar photography, substituting the precision and delicacy of the sensitized plate for the naked eye, he entered upon his investigations with new zest. The path of a large meteor, accidentally obtained by John Lewis at Ansonia, Conn., several years ago when photographing, was so successfully investigated by Professor Newton that, along with extraneous observations, he was enabled to fix accurately the direction of the meteor's fall at a point a few miles north of Danbury, Conn., and subsequently he confirmed his calculations by local data obtained near that city. It was at his suggestion and through his work in raising the funds that in 1894 a battery of cameras was placed in Yale Observatory for more expansive meteoric photography. Simultaneous observations by this instrument and at Ansonia of a meteor gave him the elements for computing its altitude and place with a possible error which he estimated at less than a mile. The fine collection of meteoric stones and irons now in the Peabody Museum at Yale is largely the harvest of his labors and

of his fame, besides a considerable private collection of his own.

Outside of these specialized paths Professor Newton during a singularly industrious life has found time for attention to other mathematical themes. Jointly with Professor Phillips of Yale he printed in 1875 a paper on "Transcendental Curves" with twenty-four plates. Other papers have been on net values of life insurance policies, on the metric system, on the law of mortality among the former members of the Yale Divinity School, and short biographies of Professor Benjamin Pierce and Professor Elias Loomis. He contributed in 1890 mathematical and astronomical definitions to Webster's International Dictionary, in 1883 the article on "Meteor, Meteorite" of the Encyclopedia Britannica, and in 1875 the articles on "Determinant" and "Meteor" to Johnson's Cyclopedia. In 1864, at his suggestion, the metric system was embodied in American arithmetics, and he has frequently predicted that its weights and measures would ere long come into common American use. He had been for many years and up to his death an associate editor of the *American Journal of Science*, and had served as President of the Connecticut Academy of Arts and Sciences and of the American Association for the Advancement of Arts and Sciences, and was one of the original promoters and, ever since it was formed, a member of the National Academy of Sciences. Among many other honors, he was a fellow of the Royal Philosophical Society of Edinburgh, and an associate of the Royal Astronomical Society of London. A few years ago he received from the National Academy the Smith gold medal in recognition of his original work in meteoric science.

In personality Professor Newton was most gracious and kindly, and, in all things simplicity itself. He was tireless in his efforts to aid poor students at Yale seeking an education, and not a few have owed to him the success of their college careers. The ordeals of his class-room were made somewhat severe by his love of problems not in the text book. It at times took a gentler shape when the Professor went to the blackboard to demonstrate briefly a problem of his own in which he soared away on the wings of his "transcendental curves" until, unwittingly, the whole recitation hour was consumed. His interest in politics was ever constant and intense, and he never flexed views which were of the old Democratic "state rights" type in times when he was the only Democrat in the Yale faculty. Elected an alderman of New Haven a few years ago in the strong Republican First Ward of that city, he was as faithful to municipal

duties as in the class-room, defying his party caucus and voting for the impeachment of the members of a "Big Four" combination for "looting" the local Board of Public Works.

Professor Newton married, April 14, 1851, Anna C., daughter of the Rev. Robert Stiles, at one time pastor of the Mercer Street Presbyterian Church in New York city and subsequently of a Presbyterian church at New Haven. She, with two daughters, survives him.—"*Evening Post*," *N. Y., Aug. 31, 1896.*

THE THEORY OF PROBABILITY.—AN HISTORICAL SKETCH.

THOS. LINDSAY, Toronto.

I. Introductory.

The history of mathematical sciences is pre-eminently a record of the progress of human thought. It lays bare the successive steps in the evolutionary process which has developed the reasoning faculties of mankind, as distinguished from those faculties which are quickened by environment alone. It points to the existence of such a thing as the love of knowledge for its own sake, for the masters in pure mathematics have passed far beyond the region of application, broadened as that region has been by modern experimental philosophy. And if here and there strongholds appear which defy all the powers of analysis they but serve as way marks pointing to the infinite vastness of the field of research. So intensely interesting a subject has formed a theme for many writers; some have selected particular epochs; others individual masters whose biographies form histories of the science of their day; and several historians, gifted with the arts of collecting and sorting have brought into comprehensive view the whole range of the process which began with counting upon the fingers and has carried us to methods that successfully reveal some, at least, of nature's most cherished secrets. From the works of such writers it is possible to gather material for a brief and possibly popular sketch of one branch of mathematics which is perhaps more fascinating to the general reader than any other and which is unique in this, that while it does not lead directly to any department of physics, it yet must be consulted by all of them. Beginning with simple, even trivial phenomena, the "Theory of Probability" has led us to where it is possible to interpret the language of experimental philosophy as if that language indeed were addressed to men—men without nerves. No experimenter ever worked, none ever can work, under the ideal conditions pre-

scribed by pure mathematics; but here is a branch of science acting as a mediator, and so grappling with ever recurring errors as to finally extinguish them, or at least reduce them to one so infinitesimal that its existence will never be known—while men continue to have nerves. This, however, is the highest flight of the science; there is a period of about a century and a half, and there are the lives of many illustrious men, to be reviewed before we reach the final triumph of Laplace nearly a hundred years ago. Then we shall find that there has been practically nothing added to the mathematics of probability since that day, the theory lies where the great Frenchman left it.

The philosophers of the ancient world seem never to have touched upon any arithmetical treatment of the occurrence of fortuitous events; to them probably there was no such thing as chance, and in any event their civilization was not of a kind likely to lead them to investigation. Gambling of some sort or other has always existed, and the drawing of lots to decide some special question has certainly been common in all ages. But the Greek philosophers no doubt were never at a loss to explain an event, after its occurrence, by referring to the intercessions of some one or other of the deities who ruled their little world. Amongst these same philosophers we find mathematicians whose work has come down to us unimproved upon through all the centuries, but that work mainly related to one science, pure geometry. Algebra, as we know it, was not employed by them, while experimental philosophy seems never to have had other than a feeble hold upon the Greek mind.

Arithmetic and algebra were developed gradually, each successive century even of the dark ages adding something, for, as has been aptly said, "When darkness overshadowed Europe, Science fled to Arabia." Then came the revival of learning, the invention of the printing press, the founding of universities, and mathematics kept pace with the arts, all tending to free the human mind from the effects of a thousand years of torpor. Galileo is called into being, he begins a system of nature questioning, and finally about the middle of the 17th century we find the world eager for knowledge of every kind. And here we meet two mathematicians who see that there is something to be learned even by studying the possible combinations in a simple game of chance. From the mere tossing of a coin there was apparently some law to be deduced. It was seen that a perfectly fortuitous event might still be predicted by noting the occurrence of like events, and the "Theory of Probability" entered into the mathematics of the day.

THE MOON. VI.

WM. W. PAYNE.

For Popular Astronomy.

To account satisfactorily for the various markings on the surface of the Moon, easily seen by the aid of the telescope, is no small task. Why this is so may not be readily understood by the ordinary reader, for such a statement seems to be inconsistent with what he has learned in reading any elementary text-book on astronomy. He knows that the Moon is comparatively near to the Earth, and he has read that careful observers have been studying its surface markings with the telescope for nearly three hundred years. He also knows that the great telescopes of the present day show wonderful things on the surface of the planet Mars at the distance of 50,000,000 of miles, and, on this account, he does not see why such powerful instruments should not reveal everything to the minutest detail, on the surface of our Moon, at the comparatively insignificant distance of 240,000 miles. In answering this point which sometimes troubles interested students, it may be well to say that large telescopes do reveal on the lunar surface a most wonderful array of minute details in the structure of objects observed, and that many of these very small markings are well and definitely seen at favorable times of viewing; but it should not be inferred certainly, that because an object is well and definitely seen, that therefore the observer knows as much about it as he would know if he had examined it under conditions with which he is particularly familiar, or, in external relation which he can fully appreciate, as he does those that constantly surround him on the Earth. The relation of the telescope to the distance of a celestial body is an important factor in the study of physical details, but this one feature is by no means all that is involved in the solution of the difficult problem of the constitution of the heavenly bodies even if we consider the nearer ones that belong to the solar system.

Observers generally believe that the Moon is nearly or quite destitute of atmosphere and water, and that the prevailing temperature of the surface is very low, probably ranging from zero to 200° or more below zero during the period of a lunar month. These conditions are so different from those with which we are familiar on the Earth, that it is evidently no easy task to interpret physical observations very fully or generally, because observers do not well enough know how terrestrial substances

with which they are best acquainted would behave themselves under such unknown conditions of atmosphere, water and temperature. On the other hand it is believed that the materials composing the surface of the Moon are solid in form at the present time and have been so for an indefinitely long period of time the extent of which astronomers have no means of calculating with any degree of certainty. If there are some advantages in the study of the solid forms of matter as such, over that of either the liquid or the gaseous, it will readily be understood by the thoughtful reader that there are also great disadvantages to be overcome, in which modern instruments and methods would be of no use at all, because not adapted to the form of matter under investigation. For this cause, probably, more than any other single one, our knowledge of the physical constitution of the Moon, and of the real causes that have operated to produce the present condition of its surface, has grown more slowly and less satisfactorily than in any other line of astronomical study. The spectroscope offers very little aid in any point of the investigation which has not been as well, or even better, shown in other ways. It is no fault of the spectroscope that this is so. The truth is that the instrument is simply a witness that refuses to reveal new knowledge in the case because of its inability to do so. Practically the same thing is true in regard to photography and other means of modern study, so very useful in other branches of the science. Hence, if the question before the mind of the astronomer is one that relates to the origin of certain formations on the lunar surface, there is only one way to grapple with it successfully in order to gain knowledge to be added to that already known, and that is the faithful use of the old and common ways of observation with the trained eye and the telescope. This part of the work is fundamental, and will require patience and time to make the mind familiar enough with what the eye sees to enable a person to form an opinion of much value. It is plainly foundation work that is very necessary either for independent thinking, or for the proper interpretation of what other astronomers have observed relating to the same objects and have described in their own language.

The next step is the collection of all the useful data that can be found bearing on the matter under consideration. In this work experience and judgment will be worth much in determining the useless and the useful data, and in selecting only that which should be retained as the basis of a worthy opinion.

The final step is that of forming a theory concerning the mat-

ter under investigation which shall explain all the known facts pertaining to it, and which shall not be inconsistent with any physical laws that ought to apply under known, existing conditions. This requires a mind endowed with rare powers of generalization and of philosophical insight; and, chiefly because all clever astronomers are not so peculiarly endowed, they differ very widely, sometimes, in the conclusions which they draw from essentially the same data.

With such thoughts as these in mind to aid us we may begin a review of what is known to astronomy about the Moon by referring first briefly to its relation to other heavenly bodies in the solar system to which it belongs.

In preceding articles we have spoken of the different motions of the Moon as related to the Earth and to the Sun, and said something about the causes of the same, and the laws governing those motions. None of these points have been treated fully because it did not seem best to do so until a general survey of our topic had been completed. Now, enough has been said that we may begin an inquiry into the probable early history of our satellite; and the query that first arises is, concerning the relation of the Moon to the Earth in very remote past time. Was it ever a part of the Earth's mass? If so, how was a separation into two masses accomplished, and are the present relations of the two bodies to remain constant for all future time? The answer to the first question is almost unanimous by scholars of the present day, and may be set down as an emphatic affirmative, but it may not be clear to all readers how astronomers have reached the conclusion that the Earth and Moon were originally parts of one common mass. To trace the growth of this opinion in a rapid and a general way, we ought to go back at least to the times of Sir William Herschel, and read his study and observations of the nebulæ. This will plainly show how a zealous and faithful seeker after truth is rewarded in persistent, self-directed effort. At the beginning of his study of the nebulæ he inclined to the belief that they were clusters of stars, so distant and so closely packed in space that their common light gave the appearance of faint cloud-like forms. After years of observation in which all kinds of nebulæ were fully considered, Herschel's views were materially changed in regard to the constitution of what he saw. He no longer thought them to be clusters of stars, but he adopted the earlier views of some of the philosophers who held that they were masses of some vapory substance in an elementary state, and in the process of condensation to form celestial bodies of

various kinds as we now know them. Consistent with this fundamental idea Herschel's extensive catalogue of the nebulæ was divided into classes recognizing an order of development, which began with the large, diffuse and ill-defined masses as the lowest, then grouped together in another class those that were milky in appearance with some evidence of condensation, next those having definite, though irregular outline, following successively with those that were round, those that were gradually brighter in the middle, those having a nucleus, those having distinctly progressive condensation, the planetary nebulæ, so called, and finally the stellar nebulæ. The perception of this law of gradation in the nebulæ was a piece of masterful insight, amounting to little less than the exalted ideas of nature's processes of development as they are understood at the present time.

As a summary of the wonderful work done by Herschel, we know of nothing better than his own words uttered near the close of his observations in this particular direction. He says: "The total dissimilitude between the appearance of a diffusion of the nebulous matter and of a star, is so striking, that an idea of the conversion of the one into the other can hardly occur to any one who has not before him the result of the critical examinations of the nubulous system which has displayed in this (his) paper. The end I have had in view, by arranging my observations in the order in which they have been placed, has been to show that the above mentioned extremes may be connected by such nearly allied intermediate steps, as will make it highly probable that each succeeding state of the nebulous matter is the result of the action of gravitation upon it while in the foregoing one, and by such steps the successive condensation of it has been brought up to the planetary condition. From this the transit to the stellar form, as it has been shown, requires but a very small additional compression of the nebulous matter."

It is doubtless well known to most of our readers that as Herschel's work closed that of the distinguished Laplace began. Herschel had shown how vast nebulous masses under the attraction of gravitation might be condensed into smaller and more regular forms and he expressed his belief that the development of the various classes of the nebulæ had been, and still was going on in the same way. Laplace went further and showed in a singularly forceful way how the law of gravitation might, and probably did, form the planets and satellites of our solar system from the later forms of the nebulæ as classified by Herschel. What the nebular hypothesis as worked out by Laplace was, is too well

known to need specification. Its principal features and its later modifications will be found in any good, modern text-book on astronomy. But a little more ought to be said at this point concerning the profound work of other scholars in the same direction at about the same time, in endeavoring to grasp the great truths of the nebular hypothesis in as much as some young readers in elementary work do not seem to comprehend very well either the nature or the real meaning of this hypothesis.

We can not now take the space to speak of the hypothesis of Swedenborg and Kant, which were essentially the same as that of Laplace, except to say that three philosophers, almost simultaneously and independently proposing such a plan for the developement of the solar system is a most astonishing thing to contemplate even now, at the end of the nineteenth century. Then bear in mind another line of investigation that began more than 200 years ago, with Newton as he experimented with the prism and its rainbow colors; but it was Wolloston who first saw the wonderful dark lines in the colored band, and yet another took the next step and began the maping of these lines and that was Fraunhofer, hence they were called Fraunhofer lines. But no one yet knew their meaning until the distinguished Kirchhoff gave the interpretation and unmistakably verified it by chemical experiments that a school boy can now easily explain. Armed with this new means of investigation, the spectroscope was eagerly turned upon the Sun and the stars and the unity and beauty of the physical universe dawned on the minds of men as they could not possibly have dreamed of it before.

Scarcely less surprising to Dr. William Huggins were the new facts shown him, when he turned his telescope with the spectroscope attached on the bright nebulæ for the first time. To his alert mind guided by a trained eye, what a moment of supreme satisfaction it must have been to him to realize, at once, something of the nature of the nebulæ which Rosse's giant telescope had failed to reveal, especially so since this new testimony powerfully supported the views of Herschel and Laplace.

The discovery of the mechanical equivalent of heat should not be overlooked in this connection in an attempt to understand fully, now, what is meant by the nebular hypothesis in the light of modern science. It should be realized how the independent discoveries of Coddington, Meyer and Jule, in the first half of this century put into the hands of physicists a ready means of calculation which advanced our knowledge in a wonderful degree concerning the operation and transformation of cosmical energy.

Neither is it less important to the student to know what has been done in the development of the theory of tidal evolution by the celebrated G. H. Darwin of England in the study of our Earth-Moon system, and more fully applied to the evolution of the star systems of the universe by the young and scholarly Dr. T. J. J. See of our own country. With all these lines of thought in mind we are ready for a more comprehensive study of the constitution and the present condition of the Moon than otherwise could be possible. Photographs of the Moon previously given and the one presented in this number will be considered later.

THE CONSTITUTION AND FUNCTION OF GASES.*

The reader who has thoroughly studied all the preceding pages of this treatise will, I think, be convinced that in the atmospheric gases are hidden forces which occasionally find manifestation in divers modes of action, as in the lightning and the tempest and, in their most awful and destructive form, in the tornado; furthermore, it will be quite apparent to said reader that the radiations emanating from the Sun are the chief—if not the only—factors operating to evoke the normally latent forces of the atmosphere, and that the operation may be caused to such an extent that it will entail disastrous results; and these are facts which ordinary as well as scientific observation has demonstrated.

While the processes of the compression of the solar matter, of the generation of heat thereby, and of the radiation of the thermal energy thus generated, are apparently, at present, progressing at a moderate rate and quite uniformly, there is no evidence or guaranty that this uniformity and moderation of action will always continue; in fact, when the heterogeneous constitution of the condensing solar matter is considered, the supposition that the process is subject to considerable, irregular and sudden changes is a most rational one, and it is quite probable that during several periods in the past the output of thermal energy from the Sun was less and during other periods greater, than the normal. For instance, the cause of what is known as "glacial period" is succeptible of explanation under several hypotheses, one of which I have advanced in the supplement to the first part of this treatise, and which suggests that, since the density of the gaseous matter known as the "luminiferous æther"

* Extract from The Constitution and Function of Gases, by S J. Corrigan, St. Paul, Minn.

is probably not uniform throughout space, and as the Sun—with the Earth and the other members of the solar system, are, as a whole moving through space and may pass through regions sometimes of comparatively dense and at other times of more tenuous ætherial matter, the rate of solar radiation is, most probably, variable, being in the former case greater, and in the latter case less than the normal, the rate being proportional to the cube root of the relative density of the gaseous matter through which the sun is passing at any time, as I have demonstrated in the first part of this treatise. But this idea concerning the cause of the "glacial period" does not preclude the hypothesis that during that period the rate of the solar radiation was below the normal, and that this reduction of rate was due to a corresponding decrease in the rate of the heat-generating compression, and it is obvious that if this rate can thus irregularly decrease, it can also increase in the same manner, and the results of such increase can be accurately predicted under the concepts of my general hypothesis.

Thus an augmentation of solar radiation through an abnormal increase of the rate of condensation of the matter now composing the Sun would—even were the consequent increase of solar temperature quite small—cause serious and even disastrous effects, because, as I have demonstrated on foregoing pages, even a small increase of temperature in the solar surface matter must cause a comparatively great output of energy therefrom, and because, as I have shown, the normal temperature of the solar photosphere—which is the effective temperature of the Sun—is so near that which would cause dissociation of the conjugate atoms of the molecules of the atmospheric gases, even at their normal density, pressure and temperature at the Earth's surface, and, therefore, disturbances of the equilibrium of the atmospheric gases and of the normal magnetic and electric neutrality of the molecules of these gases, and, consequently, all the phenomena of storms.

According to my hypothesis, and also the commonly accepted theory, a very small increase of the solar radiation would considerably accelerate the motion of the atmospheric convection currents, and also intensify those perturbations of the tenuous matter of the upper atmosphere which, in the manner I have already described, cause areas of low atmospheric pressure, or storm centres, with all their concomitant phenomena.

A sudden increase of the rate of condensation of the solar matter—one considerable, yet not adding much to the effective tem-

perature of the Sun as measured by Fahrenheit degrees—occurring, as it may, at any time, would greatly intensify each and all of these phenomena, but the effects of such increment of solar condensation might not, and probably would not, appear as heat, because the consequent increase of thermal energy would be in great part, if not wholly, expended in the work of expanding the atmospheric gases, dissociating the conjugate atoms of their molecules, developing atmospheric electricity, causing copious evaporation and uplifting aqueous vapor from the waters on the surface of the Earth, and disturbing the atmospheric equilibrium generally; air currents of great velocity and extensive cyclonic storms comparable to the tornado in intensity would result, and the seas would be lashed into a fury never before witnessed by man; furthermore, while there are scientific reasons for believing that the Earth is a very solid body, there are undoubtedly extensive faults in its superficial strata—weak parts very liable to succomb to the strains which would inevitably be caused by the commotion—and the consequent variations and shiftings of pressure, in the waters of the seas and in the atmospheric envelope of the Earth, the gases whereof, although small in density, yet aggregate an enormous weight, as I have demonstrated on preceding pages and as set forth in the table at the beginning of this part of my treatise, and the giving way of strata under such strains would cause earthquakes.

As I have indicated, the effective temperature of the Sun, at present, is nearly that which would suffice to dissociate the conjugate atoms of the atmospheric gases, even under the normal conditions, and since such dissociation of these atoms possessing innate magnetic polarities is, according to my hypothesis, the immediate cause of auroræ, and of magnetic and electric storms, and an important if not the principal factor in the generation of tornadoes, it is most probable that any increase of the solar temperature that would cause the abnormal disturbances of atmospheric equilibrium above discussed would be heralded by the occurrence of the phenomena last mentioned, in more than ordinary frequency and intensity.

Were the heat of the sun thus augmented, the appearance of that body would be altered; its light would, at first, increase from its present yellowish color to a perfect white, and, with a further augmentation of temperature, the solar disc would assume a bluish tint with a considerable loss of luminosity; finally, if the temperature were sufficiently increased, the Sun—strange as this statement may be—would become *a dark body*, although

a most intensely hot one, because the conjugate atoms of the molecules of the gaseous medium in space and those of the atmospheric molecules would be utterly dissociated by the intense thermal action, and the regular alternation and sequence of phases—of plus and minus amplitudes occurring alternately in regular order—which is essential to the production of the sensation called "light," would be seriously interrupted or even wholly destroyed; but the impacts of the dissociated atoms, and the consequent mechanical and thermal effects, would exist in maximum intensity, and although the Sun would be comparatively or even wholly dark, its heat would be most intense.

An interesting fact should be noted in this connection. Considerations arising from periodic variations in the light of some stars, and certain peculiarities of motion in the case of these bodies, have led astronomers to suspect the existence of disturbing companion stars which are comparatively dark, cold bodies. Now, while it is possible that such dark, cold masses exist, it is not easy to understand why, of two stellar bodies comparable in mass and sufficiently near each other to constitute a binary system, one should be intensely hot—as it must be in order to emit the light by which we see it—while its companion is so cold that it is comparatively dark and invisible to us; but if we regard the invisible body as being one so intensely hot that the velocity of the vibrations of its ultimate particles, and the consequent velocities of impact, are so great as to interfere with the ordinary regular process of radiation, in the manner described on preceding pages, the star would become less bright and its rays bluish, corresponding to the colors of the upper portion of the spectrum, which are the effects of vibrations of great velocity, as is well known: or the regular process may even be wholly destroyed (as, according to my hypothesis, it is in the dark region near the cathode, whence the so-called "X Rays," which are of peculiar intensity, emanate) and the star be, therefore, absolutely dark, although intensely hot. And this view is, I think, a more rational one than the former.

If the Sun, becoming hotter, should in the manner aforesaid, lose its light, or a portion thereof, the luminosity of the Moon would, obviously, decrease *æquo pede*, because the light of that satellite is only reflected sunlight. Furthermore, since the luminous vibrations emitted by the stars, and which render those bodies visible, are transmitted through space by the revolving atoms of the molecules of the gaseous matter known as the "luminiferous æther" and through those of the atmospheric gases envelop-

ing the Earth, it is evident that such dissociation of the conjugate atoms of the molecules of these gases by the increased velocity of impact emanating from the vibrations of the particles of the solar surface matter whose temperature has been augmented as aforesaid would occur that the luminous vibrations by which the stellar bodies are made visible would be so interfered with that these bodies would lose much of their luminosity or even cease to be visible; in other words, under such conditions the stars would fade from the heavens.

The statements above made concerning the probable consequences of an augmentation of solar temperature and pressure may be regarded by the reader as an overdrawn picture; but a thorough study of the subject will, probably, demonstrate that the opinions which I have expressed in this connection are inevitable conclusions from the premises of my general hypothesis concerning the constitution and functions of gases, the truth of the fundamental concepts of which hypothesis has been, I think, in several important instances, proved by the agreement between the facts of observation and the theoretical deductions from the concepts aforesaid, as a thorough perusal of all the preceeding pages of this treatise will show.

Therefore, I think that I have indicated a possible—and very probable—source of danger to the Earth and its inhabitants which has been overlooked by physicists, and that the only questions to be considered are those in regard to the possibility and probability of a considerable and comparetively sudden compression or condensation of the solar matter, and the extent and intensity of the process.

As I have remarked on a preceding page, the heterogeneous composition of the gaseous matter of the Sun indicates that variations in the rate of compression of the solar matter are more probable than uniformity; we may regard this matter as having faults in its constitution, just as the superficial strata of the Earth have faults which may cause portions of these strata, when subjected to abnormal strains, to give way, the earthquake shock being the result. Ages may elapse before such action in the solar matter and its consequent effects happen, yet they may occur on the morrow; the process may be so gradually progressive that, while it may cause serious effects upon the Earth and upon mankind, it will not be utterly disastrous; the Sun and the Earth and its atmosphere may return to conditions which, while not the same in all respects as before the abnormal disturbance, may approximate former conditions; the potencies of life may be pre-

served throughout all the perturbation and "a new Heaven and a new Earth" be the result. On the other hand, the increase of solar compression and temperature may be so great and sudden that all living terrestrial organisms will be destroyed and the terrestrial atmosphere itself be quite completely driven away from the Earth and be dissipated among the molecules of ætherial matter in space.

A consideration of all these possible—and even probable—effects of an augmentation of the solar temperature direct, most forcibly, attention to those words of Scripture which are generally regarded as referring to the consummation of all things mundane, and which, as set forth by the Evangelists, are the following:

"* * * and there shall be earthquakes in places. For there shall be then great tribulation, such as hath not been from the beginning of the world until now." "And there shall be signs in the Sun and in the Moon and in the stars, and upon the Earth distress of nations, by reason of the confusion of the roaring of the sea and of the waves; men withering away for fear and expectation of what shall come upon the whole world. For the powers of heaven shall be moved." "And immediately after the tribulation of those days the Sun shall be darkened; and the Moon shall not give her light; and the stars shall fall from heaven; *and the powers of the heavens shall be moved.* But of that day and hour no one knoweth." "For as a snare shall it come upon all that sit upon the face of the whole Earth." "For, as the lightning cometh out of the east and appeareth even unto the west, so shall also the coming of the Son of Man be. * * * And unless those days had been shortened there should no flesh be saved; but for the sake of the elect those days shall be shortened."

THE TWILIGHT.

ORRIN E HARMON.

FOR POPULAR ASTRONOMY.

THE TABLES AND THEIR EXPLANATIONS.

The tables are, for most part, self explanatory; but there are some points that will be better understood by a few words of explanation.

The formulæ by which the tables were computed, are given in the previous article.

Twilight Table I.

For Equinoxes.							For Decl. + 18° (May 11 and July 31)								
	Twilight Duration.			Sun's Amplitude at Twil'gt Limit = ch'ge in amplitude during Twilight			Twilight Duration.			Sun's Amplitude.					
										At Twilight Limit.			Change in During Twilight.		
Lat.				Amp. North.						Amp. North.					
	h	m	s	°	′	″	h	m	s	°	′	″	°	′	″
20	1	16	48	6	47	30	1	23	25	27	38	52	8	26	56
21	1	17	19	7	9	53	1	24	12	28	12	48	8	53	2
22	1	17	52	7	32	36	1	25	1	28	47	50	9	19	44
23	1	18	28	7	55	39	1	25	53	29	24	00	9	47	5
24	1	19	5	8	19	4	1	26	49	30	01	19	10	15	4
25	1	19	45	8	42	53	1	27	48	30	39	55	10	43	47
26	1	20	26	9	7	6	1	28	51	31	19	51	11	13	17
27	1	21	10	9	31	46	1	29	58	32	1	13	11	43	39
28	1	21	57	9	56	54	1	31	9	32	44	7	12	14	57
29	1	22	46	10	22	33	1	32	24	33	28	37	12	47	12
30	1	23	37	10	48	44	1	33	45	34	14	53	13	20	35
31	1	24	32	11	15	30	1	35	10	35	3	1	13	55	8
32	1	25	29	11	42	52	1	36	41	35	53	8	14	30	57
33	1	26	29	12	10	53	1	38	18	36	45	27	15	8	12
34	1	27	32	12	39	35	1	40	2	37	40	5	15	47	00
35	1	28	39	13	9	2	1	41	53	38	37	15	16	27	29
36	1	29	49	13	39	17	1	43	52	39	37	11	17	9	51
37	1	31	3	14	10	22	1	45	59	40	40	8	17	54	19
38	1	32	21	14	42	21	1	48	16	41	46	23	18	41	5
39	1	33	43	15	15	18	1	50	44	42	56	17	19	30	29
40	1	35	10	15	49	17	1	53	24	44	10	13	20	22	48
41	1	36	41	16	24	20	1	56	17	45	28	38	21	18	25
42	1	38	17	17	00	40	1	59	26	46	52	5	22	17	49
43	1	39	59	17	38	15	2	2	52	48	21	15	23	21	35
44	1	41	46	18	17	12	2	6	39	49	56	53	24	30	25
45	1	43	39	18	57	39	2	10	50	51	40	3	25	45	14
46	1	45	39	19	39	42	2	15	29	53	32	00	27	7	11
47	1	47	46	20	23	30	2	20	44	55	34	27	28	37	52
48	1	50	1	21	9	11	2	26	42	57	49	38	30	19	22
49	1	52	24	21	56	56	2	33	36	60	20	49	32	14	47
50	1	54	56	22	46	55	2	41	44	63	12	58	34	28	55
51	1	57	38	23	39	21	2	51	39	66	34	8	37	9	38
52	2	00	31	24	34	29	3	4	23	70	40	16	40	32	36
53	2	3	35	25	32	34	3	22	35	76	11	17	45	17	33
54	2	6	52	26	33	54	4	13	44	90	00	00	58	16	57
55	2	10	24	27	38	52	co ntin uo u s								
56	2	14	11	28	47	50									
57	2	18	16	30	1	20									
58	2	22	41	31	19	52									
59	2	27	29	32	44	7									
60	2	32	41	34	14	54									

The terms amplitude and azimuth mean the same thing so far as "change in amplitude" is concerned. I have preferred to express the Sun's place at the twilight limit with reference to the east and west points of the horizon; hence the term amplitude is used. The change in amplitude during twilight will be found in the last column of each table. Under the heading Table I, two tables are given. It is easy to see that, at the equinoxes, the

Twilight Table II.

	For Decl. + 23° 27′									For Decl. — 23° 27′						
	Twilight Duration. (Longe t)			Sun's Amplitude.						Sun's Amplitude.						
				At Twilight Limit.			Change in During Twilight.			At Twilight Limit.			Change in During Twilight.			
Lat				Amp. North.						Amp. South.						
	h	m	s	°	′	″	°	′	″	°	′	″	°	′	″
20	1	28	1	34	18	5	9	14	47	19	5	16	5	58	2
21	1	28	57	34	57	14	9	43	24	18	52	27	6	21	23
22	1	29	58	35	37	53	10	12	52	18	39	50	6	45	11
23	1	31	9	36	21	22	10	44	29	18	27	38	7	9	15
24	1	32	11	37	3	46	11	14	19	18	15	43	7	33	44
25	1	33	25	37	49	16	11	46	32	18	4	10	7	58	34
26	1	34	44	38	36	47	12	19	58	17	52	24	8	24	24
27	1	36	9	39	26	15	12	54	36	17	42	6	8	49	33
28	1	37	38	40	17	26	13	30	06	17	31	33	9	15	47
29	1	39	15	41	11	13	14	7	20	17	21	20	9	42	33
30	1	40	58	42	7	30	14	46	10	17	11	30	10	9	50
31	1	42	49	43	6	31	15	26	47	17	2	00	10	37	44
32	1	44	49	44	8	30	16	9	21	16	52	46	11	6	23
33	1	46	58	45	13	44	16	54	8	16	44	00	11	35	36
34	1	49	17	46	22	22	17	41	12	16	35	31	12	5	39
35	1	51	50	47	35	21	18	31	26	16	27	25	12	36	30
36	1	54	34	48	52	32	19	24	38	16	19	40	13	8	14
37	1	57	34	50	14	37	20	21	25	16	12	10	13	41	2
38	2	00	52	51	42	24	21	22	30	16	5	23	14	14	31
39	2	4	31	53	16	38	22	28	33	15	58	50	14	49	15
40	2	8	33	54	58	13	23	40	21	15	52	40	15	25	12
41	2	13	6	56	48	48	24	59	28	15	46	53	16	2	27
42	2	18	14	58	49	41	26	27	03	15	41	37	16	41	1
43	2	24	7	61	3	28	28	5	34	15	36	47	17	21	7
44	2	31	00	63	33	58	29	58	42	15	32	25	18	2	51
45	2	39	16	66	26	30	32	11	35	15	28	33	18	46	22
46	2	49	33	69	51	13	34	54	11	15	25	10	19	31	52
47	3	3	19	74	8	52	38	27	2	15	22	22	20	19	28
48	3	25	15	80	27	49	43	58	11	15	20	10	21	9	28
	continuous			Amp at Sunrise											
49				37	20	32				15	18	30	22	2	2
50				38	15	1				15	17	30	22	57	31
51				39	13	20				15	17	11	23	56	9
52				40	16	8				15	17	37	24	58	31
53				41	23	42				15	18	47	26	4	55
54				42	36	43				15	20	49	27	15	54
55				43	55	55				15	23	43	28	32	12
56				45	22	8				15	27	33	29	54	35
57				46	56	32				15	32	29	31	24	3
58				48	40	25				15	38	30	33	1	55
59				50	35	36				15	45	48	34	49	48
60				52	44	25				15	54	25	36	50	00

Sun's change in amplitude during twilight equals the Sun's amplitude at the twilight limit. For these then the Sun's amplitude, at sunrise, equals zero.

For declination + 18°, the table does not extend beyond latitude 54°; for the twilight is continuous when $\varphi + \delta = 72°$, or when $\varphi + \delta > 72°$. For declination + 23° 27′, the duration of twilight, and change in amplitude are not given beyond latitude

Twilight Table III.

Lat.	Twilight Duration for Decl. — 23° 27′ and for correlative Decls.			Correlative Declinations to — 23° 27′			Dates December 21.	Sun's Amplitude for Correlative Declinations.					
								At Twilight Limit.			Change in During Twilight.		
				Decl. North.				Amp. North.					
	h	m	s	°	′	″	and the following:	°	′	″	°	′	″
20	1	22	37	16	48	30	May 6—Aug. 5	26	13	10	8	17	50
21	1	23	10	16	29	53	May 5—Aug. 6	26	23	53	8	41	20
22	1	23	44	16	11	21	May 4—Aug. 7	26	34	48	9	4	48
23	1	24	20	15	53	00	May 3—Aug. 8	26	46	43	9	28	56
24	1	25	00	15	34	50	May 2—Aug. 9	26	59	17	9	53	23
25	1	25	41	15	16	40	May 1—Aug. 10	27	12	25	10	18	17
26	1	26	26	14	59	2	Apr. 30—Aug. 11	27	26	50	10	43	45
27	1	27	13	14	41	18	Apr. 29—Aug. 12	27	42	00	11	9	59
28	1	28	3	14	23	48	Apr. 28—Aug. 13	27	57	35	11	36	15
29	1	28	56	14	6	28	Apr. 27—Aug. 14	28	14	17	2	3	22
30	1	29	52	13	49	14	Apr. 26—Aug. 15	28	31	50	12	31	7
31	1	30	51	13	32	25	Apr. 26—Aug. 16	28	50	40	12	59	36
32	1	31	54	13	15	40	Apr. 25—Aug. 17	29	10	22	13	28	45
33	1	33	00	12	59	7	Apr. 24—Aug. 18	29	31	13	13	58	40
34	1	34	10	12	42	46	Apr. 23—Aug. 19	29	53	8	14	29	32
35	1	35	24	12	26	36	Apr. 22—Aug. 20	30	16	27	15	1	24
36	1	36	43	12	10	40	Apr. 21—Aug. 20	30	40	46	15	33	55
37	1	38	6	11	55	00	Apr. 21—Aug. 21	31	6	40	16	7	37
38	1	39	34	11	39	24	Apr. 20—Aug. 22	31	33	50	16	42	26
39	1	41	7	11	24	6	Apr. 19—Aug. 23	32	2	40	17	18	29
40	1	42	45	11	9	00	Apr. 18—Aug. 23	32	33	8	17	55	50
41	1	44	29	10	54	10	Apr. 18—Aug. 24	33	5	26	18	34	36
42	1	46	20	10	39	30	Apr. 17—Aug. 25	33	39	30	19	14	50
43	1	48	18	10	25	7	Apr. 16—Aug. 25	34	15	44	19	56	47
44	1	50	23	10	10	56	Apr 16—Aug. 26	34	54	9	20	40	35
45	1	52	36	9	57	00	Apr. 15—Aug. 27	35	34	52	21	26	14
46	1	54	57	9	43	16	Apr. 15—Aug. 27	36	18	7	22	14	2
47	1	57	28	9	29	40	Apr. 14—Aug. 28	37	4	5	23	4	17
48	2	00	10	9	16	31	Apr. 13—Aug. 29	37	53	20	23	57	00
49	2	3	2	9	3	32	Apr. 13—Aug. 29	38	45	50	24	52	40
50	2	6	8	8	50	45	Apr. 12—Aug. 30	39	42	3	25	51	34
51	2	9	27	8	38	18	Apr. 11—Aug. 30	40	42	20	26	53	53
52	2	13	3	8	25	57	Apr. 11—Aug. 31	41	47	2	28	00	15
53	2	16	55	8	13	51	Apr. 10—Sept. 1	42	56	45	29	11	03
54	2	21	8	8	2	1	Apr. 10—Sept. 1	44	12	15	30	26	59
55	2	25	44	7	50	24	Apr. 9—Sept. 2	45	34	8	31	48	39
56	2	30	45	7	39	00	Apr. 9—Sept. 2	47	3	24	33	17	5
57	2	36	17	7	27	49	Apr. 8—Sept. 3	48	41	10	34	53	17
58	2	42	25	7	16	48	Apr. 8—Sept. 3	50	28	50	36	38	44
59	2	49	17	7	5	57	Apr. 7—Sept. 4	52	28	23	38	35	20
60	2	57	1	6	55	14	Apr. 7—Sept. 4	54	42	13	40	45	31

48°. The lowest latitude of continuous twilight is 48° 33′. Beyond 48°, the amplitude at sunrise is given for decl. + 23° 27′. The complement of the amplitude at sunrise is the change in amplitude from midnight till sunrise.

Under Table II, the amplitude at twilight limit and change in amplitude are also given for decl. — 23° 27′. The twilight duration for decl. — 23° 27′ is given in Table III. This duration is

Twilight Table IV.

The Shortest Twilight.

Lat.	Twilight Duration (Shortest) h	m	s	Sun's Declination South. °	′	″	Dates.	Sun's Amplitude. At Twilight Limit. Amp. North. °	′	″	Change in During Twilight. °	′	″
20	1	16	40	3	6	19	Mar. 12—Sept. 30	3	18	20	6	36	38
21	1	17	10	3	15	14	Mar. 12—Oct. 1	3	29	00	6	58	8
22	1	17	42	3	24	5	Mar. 11—Oct. 1	3	40	15	7	20	23
23	1	18	17	3	32	53	Mar. 11—Oct. 1	3	51	10	7	42	28
24	1	18	53	3	41	37	Mar. 11—Oct. 2	4	2	35	8	5	12
25	1	19	31	3	50	16	Mar. 10—Oct. 2	4	14	00	8	28	7
26	1	20	11	3	58	52	Mar. 10—Oct. 2	4	25	50	8	51	39
27	1	20	54	4	7	25	Mar. 10—Oct. 3	4	37	40	9	15	24
28	1	21	38	4	15	52	Mar. 9—Oct. 3	4	49	40	9	39	32
29	1	22	26	4	24	14	Mar. 9—Oct. 3	5	2	5	10	4	17
30	1	23	15	4	32	32	Mar. 8—Oct. 4	5	14	45	10	29	33
31	1	24	7	4	40	45	Mar. 8—Oct. 4	5	27	30	10	55	10
32	1	25	2	4	48	52	Mar. 8—Oct. 5	5	40	45	11	21	32
33	1	26	00	4	56	55	Mar. 7—Oct. 5	5	54	5	11	48	9
34	1	27	1	5	4	53	Mar. 7—Oct. 5	6	7	55	12	15	53
35	1	28	5	5	12	44	Mar. 7—Oct. 6	6	22	10	12	44	12
36	1	29	12	5	20	30	Mar. 6—Oct. 6	6	36	30	13	12	58
37	1	30	22	5	28	11	Mar. 6—Oct. 6	6	51	5	13	42	22
38	1	31	36	5	35	45	Mar. 6—Oct. 7	7	6	35	14	13	4
39	1	32	54	5	43	13	Mar. 5—Oct. 7	7	22	5	14	44	12
40	1	34	16	5	50	36	Mar. 5—Oct. 7	7	38	10	15	16	24
41	1	35	42	5	57	52	Mar. 5—Oct. 8	7	54	45	15	49	35
42	1	37	13	6	5	1	Mar. 4—Oct. 8	8	11	55	16	23	51
43	1	38	48	6	12	4	Mar. 4—Oct. 8	8	29	40	16	59	16
44	1	40	29	6	19	00	Mar. 4—Oct. 9	8	47	55	17	35	48
45	1	42	15	6	25	49	Mar. 3—Oct. 9	9	6	43	18	13	30
46	1	44	7	6	32	31	Mar. 3—Oct. 9	9	26	20	18	52	43
47	1	46	5	6	39	7	Mar. 3—Oct. 10	9	46	45	19	33	30
48	1	48	10	6	45	34	Mar. 3—Oct. 10	10	7	50	20	15	43
49	1	50	21	6	51	55	Mar. 2—Oct. 10	10	29	50	20	59	43
50	1	52	41	6	58	8	Mar. 2—Oct. 10	10	52	48	21	45	37
51	1	55	9	7	4	14	Mar. 2—Oct. 11	11	16	42	22	33	26
52	1	57	45	7	10	11	Mar. 1—Oct. 11	11	41	46	23	23	32
53	2	00	32	7	16	1	Mar. 1—Oct. 11	12	7	55	24	15	54
54	2	3	29	7	21	43	Mar. 1—Oct. 11	12	35	28	25	10	57
55	2	6	37	7	27	17	Mar. 1—Oct. 12	13	4	22	26	8	46
56	2	9	58	7	32	42	Feb. 28—Oct. 12	13	34	53	27	9	43
57	2	13	32	7	38	00	Feb. 28—Oct. 12	14	7	2	28	14	1
58	2	17	21	7	43	9	Feb. 28—Oct. 12	14	41	00	29	21	58
59	2	21	27	7	48	10	Feb. 28—Oct. 13	15	17	3	30	34	5
60	2	25	51	7	53	2	Feb. 28—Oct. 13	15	55	20	31	50	40

also the duration for the declinations correlative to — 23° 27′; but the amplitude refers only to the correlative declinations. December 21, is the time when the Sun attains decl. — 23° 27′. The dates below are the times when the Sun reaches the correlative declinations. The date in the other tables are the dates when the Sun reaches the declinations therein given, and the corresponding twilight duration, etc., are produced.

Twilight Table V.

When the Middle of the Twilight is Six O'clock.

Lat.	Twilight Duration. h	m	s	Sun' Declination South. °	′	″	Dates.	Sun's Amplitude. At Twilight Limit. Amp. South. °	′	″	Change in Dur ing Twilight. °	′	″
23	1	24	14	23	17	35	Dec. 27—Dec. 15	18	17	13	7	9	17
24	1	24	17	22	19	33	Jan. 7—Dec. 4	17	00	40	7	33	37
25	1	24	26	21	26	40	Jan. 13—Nov. 28	15	49	16	7	58	10
26	1	24	41	20	38	16	Jan. 17—Nov. 24	14	42	26	8	22	55
27	1	25	1	19	53	50	Jan. 20—Nov. 20	13	39	20	8	48	2
28	1	25	26	19	12	54	Jan. 23—Nov. 17	12	39	37	9	13	30
29	1	25	56	18	35	4	Jan. 26—Nov. 15	11	42	50	9	39	20
30	1	26	30	18	00	00	Jan. 28—Nov. 13	10	48	44	10	5	36
31	1	27	8	17	27	26	Jan. 30—Nov. 11	9	56	52	10	32	18
32	1	27	50	16	57	7	Feb. 1—Nov. 9	9	7	5	10	59	28
33	1	28	37	16	28	50	Feb. 3—Nov. 7	8	19	4	11	27	11
34	1	29	27	16	2	24	Feb. 4—Nov. 6	7	32	37	11	55	29
35	1	30	22	15	37	38	Feb. 5—Nov. 4	6	47	30	12	24	26
36	1	31	20	15	14	25	Feb. 7—Nov. 3	6	3	35	12	54	2
37	1	32	23	14	52	35	Feb. 8—Nov. 2	5	20	40	13	24	26
38	1	33	29	14	32	4	Feb. 9—Nov. 1	4	38	45	13	55	30
39	1	34	41	14	12	45	Feb. 10—Oct. 31	3	57	35	14	27	23
40	1	35	56	13	54	30	Feb. 11—Oct. 30	3	16	50	15	00	23
41	1	37	17	13	37	18	Feb. 12—Oct. 29	2	37	00	15	34	00
42	1	38	42	13	21	2	Feb. 12—Oct. 28	1	57	20	16	8	50
43	1	40	13	13	5	39	Feb. 13—Oct. 27	1	17	50	16	44	53
44	1	41	49	12	51	5	Feb. 14—Oct. 27	0	39	00	17	21	40
45	1	43	31	12	37	17	Feb. 15—Oct. 26	0	00	00	18	00	00
								Amp. North. °	′	″			
46	1	45	19	12	24	12	Feb. 15—Oct. 25	0	39	00	18	39	40
47	1	47	13	12	11	47	Feb. 16—Oct. 25	1	17	50	19	20	33
48	1	49	14	12	00	00	Feb. 16—Oct. 24	1	57	20	20	3	28
49	1	51	23	11	48	48	Feb. 17—Oct. 24	2	36	50	20	47	47
50	1	53	39	11	38	10	Feb. 17—Oct. 23	3	17	00	21	34	14
51	1	56	4	11	28	4	Feb. 18—Oct. 23	3	57	40	22	22	40
52	1	58	38	11	18	27	Feb. 18—Oct. 22	4	38	50	23	13	6
53	2	1	21	11	9	18	Feb. 19—Oct. 22	5	20	40	24	5	46
54	2	4	16	11	00	37	Feb. 19—Oct. 21	6	3	40	25	1	20
55	2	7	22	10	52	20	Feb. 20—Oct. 21	6	47	30	25	59	26
56	2	10	41	10	44	28	Feb. 20—Oct. 21	7	32	40	27	00	47
57	2	14	12	10	36	58	Feb. 20—Oct. 20	8	19	7	28	5	23
58	2	18	00	10	29	51	Feb. 21—Oct. 20	9	7	7	29	13	41
59	2	22	4	10	23	5	Feb. 21—Oct. 20	9	56	56	30	26	8
60	2	26	26	10	16	38	Feb. 21—Oct. 19	10	48	42	31	43	2

Except as before stated, the latitudes range from 20° to 60°. But in Table V, the latitude begins with 23°, for the reason that below latitude 22° 50′ 47″ the middle of the twilight is always earlier than six o'clock. This is easily shown by the formula

$$\sin \delta = \frac{\sin 18^\circ}{2 \sin \varphi},$$

which is the formula for finding the Sun's declination when the middle of the twilight is six o'clock. If in this formula, we put $\delta = -23^\circ\ 27'$, we find the corresponding value of $\varphi = 22^\circ\ 50'\ 47''$. Hence the formula does not apply below this latitude.

The twilight duration is the twilight hour angle, in arc, reduced to Sidereal time.

In Table IV, it will be observed that the change in amplitude is equal to twice the amplitude at the twilight limit; and in Table V it will be observed that, at the twilight limit, the amplitude is south until latitude 45° is reached. Here the amplitude = 0. Above latitude 45°, the amplitude is north, and has the same value as below 45° taking the latitudes at equal distances from 45°.

For instance, the amplitude, at the twilight limit, when the middle of the twilight is six o'clock, is the same for $45^\circ + a$, as for $45^\circ - a$, only the amplitudes have opposite signs. The reason of these "peculiarities" will be explained in a future article. The results in the tables may vary a few seconds from the theoretical value.

If t = the twilight duration, in arc, and c = change in amplitude during twilight, then the following relations must exist:

$$\cos t = \frac{\cos c \cos 18^\circ - \sin^2 \delta}{\cos^2 \delta}.$$

If we put $\cos h = \cos c \cos 18^\circ$, then we have

$$\sin \frac{1}{2} h = \cos \delta \sin \frac{1}{2} t.$$

Again, if am = Sun's amplitude at sunrise, then

$$\tan k = \frac{\sin c \tan \varphi}{\cos am}; \quad \cot D = \frac{\sin k}{\tan c};$$

and

$$\sin t = \frac{\sin (18^\circ + k) \sin D}{\cos \delta}.$$

These formulæ serve to test the accuracy of the results given in the tables.

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THE FIXED STARS—VII.

W. H. S. MONCK.

If we include under the head of double or binary stars all stellar systems which contain more than one member, double stars are probably the rule not the exception in the stellar regions. Thus, the Sun is a double or multiple star, and if the surface of Jupiter was as bright as that of the Sun the difference between the two when seen from say α Centauri would only amount to about five magnitudes. With many known double stars the difference is as great as this: and if Jupiter is not self-luminous (though many astronomers think that he has some light of his own) we have seen that some of the stars have dark satellites proportionally larger than any within the solar system. Most of our nearer neighbors among the fixed stars are known to be double stars. α Centauri and 61 Cygni are visibly so. The satellite of Sirius was discovered though with greater difficulty and the existence of the satellite of Procyon has been shown by the irregular motion of the star. That the satellites of very distant stars should not be discovered except under unusual circumstances is not surprising. Thus Arcturus which seems single is computed to be twenty times as remote as Sirius. If Sirius was removed to this distance and its own light and that of its satellite kept constant, notwithstanding the removal, the latter would be permanently lost in the glare of the great star so far as any existing telescope is concerned. But in fact the light of both stars would be reduced by six or seven magnitudes in consequence of the removal, and this reduction would make the satellite so faint that it would escape notice even if its angular distance was large enough to admit of separation. It is true no doubt that only a comparatively small number of observed double stars have been proved to be binary, *i. e.*, to form a physical system. But there are very strong reasons for believing that they are almost all binaries and that our failure to obtain orbits hitherto arises from errors of observation combined with the great length of their periods of revolution. Not only is the number of cases in which we find a pair of stars apparently close to each other much greater than chance will account for, but double stars obey laws which seem quite inconsistent with the supposition that they are merely stars situated at great distances from each other which happen to be nearly in the same direction when viewed from the Earth. Thus when they are of the same color, they are

usually nearly of the same magnitudes: and when the colors differ the fainter star appears to be invariably the bluer of the pair. In many cases also where orbits cannot as yet be computed, the stars have a common proper motion in space. Such pairs as I have been describing exist in thousnnds, nay, tens-of-thousands all over the sky, and every year observers are finding out that stars hitherto supposed to be single are really double. We have indeed evidence of much more extensive systems—star clusters containing thousands of stars—and stars displaying a connection by their common proper motion though their distance from each other is probably greater than that of α Centauri from the Sun. It is even a question whether all visible stars are not physically connected as parts of one vast system: but this is not inconsistent with the general statement that what appear to us a single star in our survey of the sky are for the most part really double or multiple, the companions not being seen because they are either too faint or too close to their principal. Thus the Earth and Moon form a binary system though both are members of the larger solar system.

The apparent separation of two such stars depends on several circumstances, their distance from each other, their distance from us, the shape of the orbit and the inclination of the plane of the orbit to the line of sight. Another circumstance influences the period of revolution, viz., the mass of the system. In general, however, it may be laid down that an orbit of moderate period where the two stars are separated without much difficulty in the telescope is a proof of comparative nearness—the alternative supposition being very great mass. The true orbit of the star as already noticed, depends on the assumption that the pair are moving under the influence of gravitation, but of course the apparent orbit is described in the same time as the true orbit and the observed separation refers to the apparent orbit only. Now it has been already suggested that solar stars are much more numerous relatively to Sirians than spectroscopic observations would lead us to suppose. The Solar stars are invisible or too faint to ascertain the true character of their spectra under circumstances when the Sirians are visible and their spectra ascertainable. No doubt almost all stars whose spectra have hitherto been ascertained are in a wider sense comparatively near us, but the Solars seem to be on the average much nearer than the Sirians. This theory can be partially tested by an examination of the spectra of binary stars whose orbits have been computed. Examining Dr. T. J. J. See's list with this object I have found

that fully three fourths of them were Solar stars. It might be supposed that Sirian stars were less likely to enter into binary systems. But I cannot find that this is the case. Taking up the test in Crossley Gledhill and Wilson's *Handbook of Double-Stars* I was able to identify several hundreds of them with the *Draper Catalogue* and I found that the distribution of spectra was fairly normal. Sirian double stars seemed to be quite as numerous as Solars, but as a rule they revolved so slowly that their orbits could not be computed without many years of additional observation. But when the solar class is sub-divided into Capellan and Arcturian, the difference becomes more striking. The Arcturian binaries are even less numerous than the Sirians while the Capellan binaries considerably outnumber both taken together. A decided preponderance of Capellan stars among our nearer neighbors is thus indicated unless these stars have some peculiar tendency to form binary combinations.

For the most part binary stars with short periods are so close to each other that they can only be separated with powerful telescopes under favorable circumstances and the difficulty of measuring the distances exactly renders the orbits to a considerable extent doubtful. One of the best determined orbits is that of the star ξ Ursæ Majoris whose period is about 60 years, the semi-axes major of the ellipse being about 2½ seconds. α Centauri, our nearest neighbor, has a period of about 80 years not yet exactly determined. The separation of the pair is always pretty wide owing no doubt to the nearness of the star. The orbit of 61 Cygni cannot be said to be known though several attempts have been made to compute it. The separation of this pair however is very wide. γ Virginis is an easily separable pair with a moderate period. Of course the distance between a pair of stars is often very different at different parts of the orbit. A great part of the orbits hitherto computed are highly eccentric (differing in this respect from those of our planets—indeed in many cases the eccentricity exceeds that of more than one periodic comet) and the contrast of distance may be rendered greater by the position of the orbit-plane. Thus it often happens that at one part of the orbit the stars cannot be separated while at another part a telescope of very moderate pretensions will suffice for that purpose.

On the assumption that there is no absorption of light in space we can compare the brilliancy of different binary systems with each other—brilliancy being measured by the amount of light given by the unit of surface, supposing them all to be spheres of

equal density. Of course this may not be the real explanation of the differences which are thus detected. There is reason to believe that the superior brilliancy of Sirian stars arises not altogether from the unit of surface being more intensely illuminated but also from the surface being larger relative to the mass—the density being less. The figures however do not lose their interest from the fact that there is more than one way of explaining them. The principle is briefly as follows. Suppose two binary systems revolving in similar orbits and parallel planes. Suppose their distance from us, the apparent distance between the two components and the magnitude of the stars composing the two systems, to be also the same, but the periods to be different what is the consequence? That the mass of the system which revolves most rapidly is greatest and that consequently it emits less light relatively to its mass than the other system. The same result would follow if the periods were equal but the apparent separation of one pair was less than that of the other. The most widely separated pair would have a greater mass than the other and wonld therefore emit less light relatively to its mass. Nor is the assumption that the two pairs are equally distant from us necessary. Suppose two pairs perfectly alike in their orbits and visual magnitudes, one of which is twice as far off as the other. It must emit four times as much light since light diminishes as the inverse square of the distance. Supposing the brilliancy of the two pairs to be equal, it will therefore present four times the amount of illuminated surface and will consequently have eight times the mass of the other: but the real separation of the two companions being doubled while the mass is eight times greater the period will be the same. The same reasoning is evidently applicable to any other augmentation of distance: and we can thus compare two systems whose distances from us are unequal by supposing a pair equivalent to the former placed at the distance of the latter. I reduced the comparison some time ago to a mathematical formula which however is liable to some error where the stars composing the one pair are more unequal in magnitude than those composing the other. It is

$$\frac{K_1}{K_2} = \left(\frac{I_1}{I_2}\right)\left(\frac{P_1}{P_2}\right)^{\frac{4}{3}}\left(\frac{a_2}{a_1}\right)^2$$

where K_1 K_2 represent the brilliancy of the two pairs, I_1 I_2 the actual amounts of light which we receive from them (which may be measured by a photometer), P_1, P_2 their periods and a_1, a_2 the respective semi-axes of their orbits as measured in seconds of an

arc. Professor Pickering had previously reached similar results from a different point of view.

On applying this formula to the Arcturian binaries I obtained very anomalous results, γ Leonis heading the list with a brilliancy of 93 (as compared with ξ Ursæ Majoris which was adopted as the standard star in my comparison), while 61 Cygni figured almost at the bottom with a brilliancy far below unity. But these Arcturian binaries were few in number and their orbits were in more than one case doubtful, so that their true position in the list still remains to be ascertained. Setting them aside, the superior brilliancy of the Sirians to the Capellans was unmistakable. No Capellan binary was as brilliant as the average Sirian: no Sirian binary fell as low as the average Capellan. I originally got a very low brilliancy for two Sirian couples. I afterwards found that in working out the formula logarithmically I had used the wrong characteristic. Mr. Gore corrected the mistake. The list no donbt presents some anomalies, some individual Capellan stars standing higher than some individual Sirians, but on the average the brilliancy of the latter is probably seven times as great as that of the former. The consideration of binary stars with computed orbits thus affords a double confirmation of the results with regard to Sirian and Capellan stars which had been derived from their proper motions. One confirmation is afforded by their relative numbers—the other by their relative brilliancy.

Ternary systems are by no means unusual among the stars. One of the commonest kinds is when the smaller star of a pair is found to be itself double. In such cases the orbit of the close pair is generally much shorter and more easily determined. Quadruple stars also often occur. Thus the well-known ϵ Lyræ almost certainly forms a binary system (though the period is very long) both components being themselves binaries. The quadruple star in the Great Nebula of Orion and perhaps some of the fainter stars in their neighborhood seem to be connected with the nebula and being nearly at the same distance from us cannot fail to form a system. Quintuple systems may also be found and so on until we proceed from binary stars up to the great clusters which contain many thousands all of which evidently possess a physical connection as appears from the mode of aggregation. In several instances the cluster appears to be globular. In many parts of the sky where the stars occur thickly though not in what would be ordinarily called a cluster we find them arranged in shapes which seem plainly to indicate some kind of physical connection. The

real shape is of course partly concealed owing to the effect of perspective, but the symmetry of the arrangement cannot be the result of chance. Stars are often arranged in a line and still more frequently in a kind of circle or else they collect into numerative clusters. In sweeping over a part of the sky where there are no conspicuous stars I have noticed how often when I met one a little brighter than the rest I met another like it immediately afterwards though not near enough to constitute a double star. Stars situated at considerable distances from each as often indicate physical connection by their common proper motion. Such motion however should be ascertained by careful measurement (including spectroscopic measures) before giving a positive opinion on this point since the motion of the solar system always tends to impress an apparent common proper motion on all stars in the same region of the sky. I do not think for instance that common proper motion has been proved in the case of five of the seven stars of the Plough which seem to have a common drift. More accurate measures of their motions do not agree well with each other. Nevertheless, if we take up a list of stars with large proper motions (and small proper motions can seldom be relied on as accurate) we cannot but be struck by their similarities. These are not for the most part conspicuous stars. But we could make out as good an agreement (perhaps better) between Sirius Arcturus and Procyon as between the five stars of the Plough. Stars situated at great angular distances from each other can hardly be influenced directly by each other's attraction. But a common origin is possible, the stars moving one after another in similar paths through the heavens as some comets appear to do. If however the two stars formed a system in which the motion was parabolic or hyperbolic they would probably be moving away from each other instead of following the same path. There are one or two instances of this among stars having large proper motions but the number is not sufficient to draw any positive inference.

Nor is it among stars only that these physical connections obtain. That there is a connection between certain stars and certain nebulæ does not seem to admit of doubt. I am of course referring to true nebulæ. A distant cluster of stars often resembles a nebula and it is only by the aid of the spectroscope that the distinction can be detected with accuracy. A true nebula presents the bright-line spectrum of a gas instead of the continuous spectrum of a star. But even without the aid of the spectroscope it would hardly be possible to doubt for instance that the nebulæ

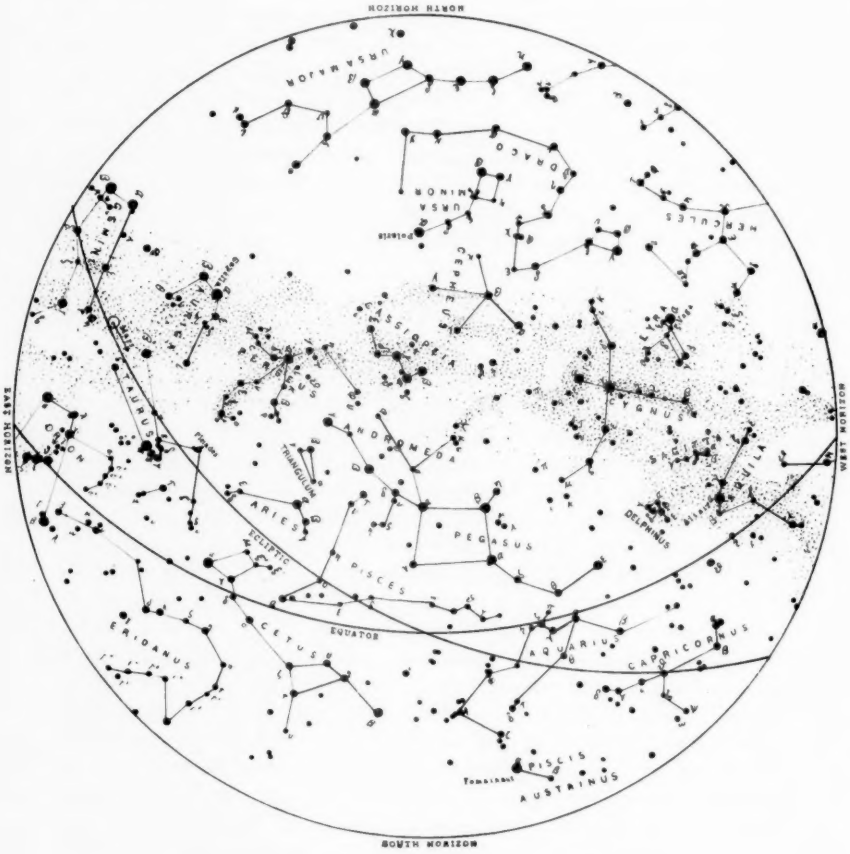
surrounding Merope and Maia in the Pleiades are true nebulæ though really connected with these stars. The finest specimens of this kind Nubecula Major and Nubecula Minor are only to be seen in southern latitudes but there are abundant proofs of the connection in the northern sky. Indeed the two classes run into each other almost imperceptibly. We have stars of a bright line spectrum resembling that of a nebula. We have stars apparently forming the nucleus of a small spherical nebula. We have what appear to be true nebulæ with spectra approaching closely to those of the stars. Star-clusters perhaps differ from nebulæ chiefly in representing different stages of star-life and in some cases like the Nubecula we have the earlier and later stages presented to us side by side, the process of formation being slowly carried on under our very eyes. The greater part of the comets too seem to belong to the stellar system. Their paths are nearly parabolic and they seem to come to us from the stars and go back to the stars again. Several of them indeed appear as if thrown off by the same star, for besides travelling nearly in the same path they resemble each other in appearance. As they would take a long time to travel from even the nearest fixed star and the star is moving during this time we cannot expect their aphelia (the points from which they come and to which they return) to coincide with the present position of the generating star, but one fine series of Sun-grazing have their aphelia at no great distance from the direction of Sirius and there appears to be a tendency in the aphelia of comets to congregate about the milky way. This is not the place to investigate the relations between comets and meteors (or shooting-stars). But for several large meteors (or fire-balls as large ones are called) hyperbolic orbits have been computed. If these orbits are correct such meteors must be visitors from external space and will leave us again to visit the stellar regions. Nebulæ comets and meteors are no doubt all gravitating bodies which must be attracted by the stars and attract the latter though less powerfully. Gravitation is as universal as the ether which conveys light to us. Does that ether convey gravitation also? It is undoubtedly the medium by which other attractive or repulsive forces—electricity for instance—are conveyed; and I confess that when I contemplate the action of the Sun on a comet for instance —in which case we have distinct evidence of both attraction and repulsion—I can scarcely believe that one of the contending influences acts immediately without any medium while the other is transmitted through a medium in a measurable time. Electric repulsion is heavily handicapped by the long start which is thus

given to gravitative attraction. But the whole question of the relation between this ether and ponderable matter stands in need of further investigation.

THE PLANETS AND CONSTELLATIONS FOR NOVEMBER.

H. C. WILSON.

Mercury is a morning planet and is now receding from us on his way around behind the Sun. He will be at superior conjunction at noon, November 28.

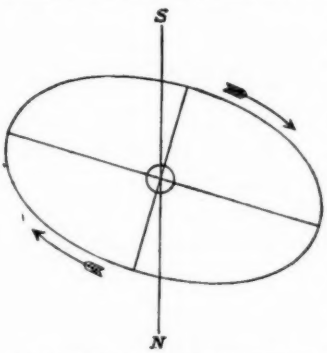


THE CONSTELLATIONS AT 9h P. M., NOVEMBER 1, 1896.

Venus is evening planet, seen toward the southwest a short time after sunset. The phase of Venus is gibbous, decreasing from 0.87 to 0.80 during the month, while the brightness of the planet increases in the ratio of 62 to 73 in the same time.

Mars is approaching opposition but will not reach it until December. The position of Mars is found on our chart of the constellations this month. It is just turning the loop in its apparent path and beginning retrograde, or western, motion among the stars between Gemini and Taurus. By this time, probably, our readers will have become familiar with the appearance of Mars as seen among the stars toward the east after 9 o'clock P. M. The planet is very bright, three or four times as bright as any of the stars in that region of the sky, and is redder even than the star Aldebaran (α Tauri). The Moon will pass Mars at about 11^h A. M., Nov. 22. The satellites of Mars may be observed now, with large telescopes. We give among the tables the times of their greatest elongations from the planet.

Jupiter may be seen in the morning, near the center of the constellation Leo. Jupiter will be just 90° west from the Sun, *i. e.*, at quadrature, Nov. 30. On the morning of Nov. 28 the planet will be 3° north of the waning Moon.



APPARENT ORBIT OF NEPTUNE'S SATELLITE.

Saturn and *Uranus* are out of position for observation, Saturn passing conjunction with the Sun Nov. 13 and Uranus being in the same position Nov. 16.

Neptune comes to opposition Dec. 10 and so is now in good position for observation. It is in Taurus, in R. A. $5^h\,16^m\,24^s$; Decl. + 21° 38′, Nov. 1, and will move very slowly westward. The satellite of Neptune can be seen only with the aid of a powerful telescope. The accompanying cut shows the apparent path of the satellite around the planet. The satellite is seen most easily when it is at the ends of the oval. The times when it will occupy these positions in November are as follows:

ELONGATIONS OF THE SATELLITE OF NEPTUNE.

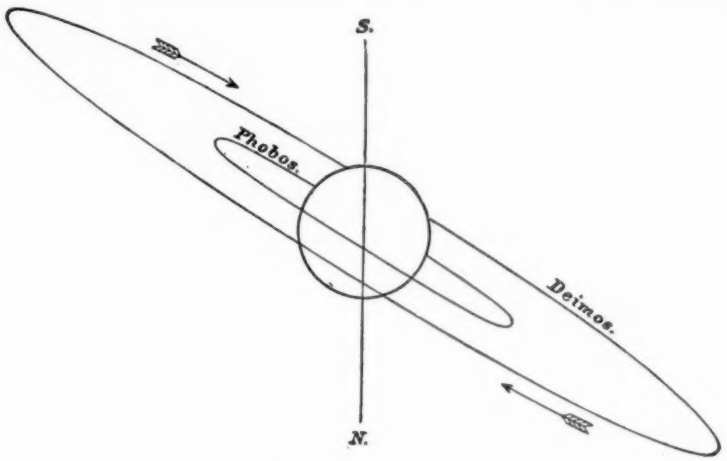
East		West	
	h		h
Nov. 4	6.6 A. M.	Nov. 1	8.0 A. M.
10	3.7 "	7	5.1 "
16	12.7 "	13	2.2 "
21	9.8 P. M.	18	11.3 P. M.
27	6.9 "	24	8.4 "
		30	5.5 "

Occultations Visible at Washington.

Date 1896.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle from N pt.	EMERSION. Washington M. T.	EMERSION. Angle from N pt.	Duration.
			h m	°	h m	°	h m
Nov. 9	h^2 Sagittarii	5.4	5 3	67	6 22	245	1 19
9	h^1 Sagittarii	7.4	5 7	15	5 57	299	0 50
12	B.A.C. 7740	7.0	6 27	99	7 23	183	0 56
19	19 Tauri	5.0	17 24	98	18 22	254	0 58
19	*g* Pleiadum	6.3	17 28	150	17 54	201	0 26
19	21 Tauri	7.0	17 44	80	18 41	273	0 57
19	20 Tauri	5.0	17 47	126	18 31	227	0 44
19	22 Tauri	7.0	17 48	87	18 45	266	0 47
19	B.A.C. 1171‡	7.8	19 3	146	19 30	207	0 27
23	B.A.C. 2363	7.3	10 24	126	11 25	242	1 1
23	52 Geminorum	6.3	10 24	85	11 36	284	1 12
24	7 Cancri.†	6.3	8 21	41	8 50	335	0 29
24	μ^2 Cancri	5.7	9 58	129	10 53	251	0 55
24	B.A.C. 2788	6.0	17 38	89	18 42	331	1 4
25	68 Cancri	7.5	10 59	172	11 34	231	0 35
25	B.A.C. 3103	7 5	13 3	68	13 58	338	0 55
28	*v* Leonis	4.4	13 13	99	14 8	321	0 55

The Satellites of Mars.

PHOBOS.			PHOBOS, Con't.			DEIMOS.		
	h m			h m			h m	
Nov. 1	6 51	P. M. W	Nov. 16	10 23	P. M. E	Nov. 2	12 34	A. M. E
1	10 41	" E	17	5 31	" W	2	3 43	P. M. W
2	5 49	" W	17	9 20	" E	3	10 1	" W
2	9 38	" E	18	1 10	A. M. W	5	4 19	A. M. W
3	8 36	" E	18	8 18	P. M. E	5	7 28	P. M. E
4	12 26	A. M. W	19	12 7	A. M. W	7	1 46	A. M. E
4	7 34	P. M. E	19	7 15	P. M. E	7	4 55	P. M. W
4	11 24	" W	19	11 5	" W	8	11 12	" W
5	6 32	" E	20	6 13	" E	9	2 20	" E
5	10 22	" W	20	10 2	" W	10	5 29	A. M. W
6	5 29	" E	21	5 10	" E	10	8 38	P. M. E
6	9 19	" W	21	9 0	" W	12	2 55	A. M. E
7	1 8	A. M. E	22	12 49	A. M. E	12	6 4	P. M. W
7	8 16	P. M. W	22	7 57	P. M. W	14	12 21	A. M. W
8	12 6	A. M. E	22	11 47	" E	14	3 29	P. M. E
8	7 14	P. M. W	23	6 54	" W	15	9 46	" E
8	11 4	" E	23	10 44	" E	17	4 3	A. M. E
9	6 12	" W	24	5 52	" W	17	6 12	P. M. W
9	10 2	" E	24	9 42	" E	19	1 28	A. M. W
10	5 9	" W	25	1 31	A. M. W	19	4 37	P. M. E
10	8 59	" E	25	8 38	P. M. E	20	10 53	" E
11	12 48	A. M. W	26	12 28	A. M. W	22	5 10	A. M. E
11	7 56	P. M. E	26	7 36	P. M. E	22	8 18	P. M. W
11	11 46	" W	26	11 26	" W	24	2 34	A. M. W
12	6 54	" E	27	6 33	" E	24	5 42	P. M. E
12	10 44	" W	27	10 22	" W	25	11 58	" E
13	5 51	" E	28	5 31	" E	26	3 7	" W
13	9 40	" W	28	9 21	" W	27	9 23	" W
14	1 30	A. M. E	29	1 10	A. M. E	29	3 39	A. M. W
14	8 38	P. M. W	29	8 18	P. M. W	29	6 47	P. M. E
15	12 28	A. M. E	30	12 7	A. M. E	31	1 3	A. M. E
15	7 36	P. M. W	30	7 14	P. M. W			
15	11 25	" E	30	11 4	" E			
16	6 33	" W						



APPARENT ORBITS OF THE SATELLITES OF MARS AS SEEN IN AN INVERTING TELESCOPE.

Ephhemeris for Physical Observation of Mars.

(From *Monthly Notices, R. A. S.*, April, 1896.]

Greenwich Noon.	Position Angle of Axis. °	Areographic Latitude Center of Disk. °	Areographic Longitude Central Meridian. °	Passage of Zero Meridian. (Cen. St'd Time.) h m
Nov. 2	333.21	+ 2.64	48.31	2 42 A. M.
4	333.20	2.54	30.10	3 57 "
6	333.15	2.41	11.94	5 11 "
8	333.08	2.26	353.84	6 25 "
10	332.98	2.08	355.78	7 39 "
12	332.85	1.87	317.78	8 53 "
14	332.69	1.63	299.83	10 7 "
16	332.50	1.37	281.92	11 20 "
18	332.29	1.08	264.07	12 33 P. M.
20	332.05	0.77	246.26	1 46 "
22	331.79	0.44	228.49	2 59 "
24	331.51	+ 0.08	210.76	4 12 "
26	331.21	− 0.29	193.07	5 25 "
28	330.89	0.67	175.42	6 37 "
30	330.57	— 1.07	157.80	7 49 "

Notation of New Asteroids.—The Berlin *Rechen-Institut* has given permanent numbers to the following recently discovered asteroids:

Planet.	Discoverer.	Date.	No.
CE	Charlois	1895 Dec. 9	(409)
CH	"	1896 Jan. 7	(410)
CJ	"	Jan. 7	(411)
CK	Wolf	Jan. 7	(412)
CL	"	Jan. 7	(413)
CN	Charlois	Jan. 16	(414)
CO	Wolf	Feb. 7	(415)
CS	Charlois	May 4	(416)
CT	Wolf	May 6	(417)

CM (Charlois, Jan. 16) proved to be identical with (332) *Siri*. *CP*, *CQ* and *CR* have not been sufficiently observed to permit determination of their orbits. The planet (352) = 1893 *B* has received from its discoverer, Professor Wolf the name *Gisela*.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1896.

	d	h
Dec.	1	15
	6	15
	11	14
	16	14
	21	13
	26	13
	31	13

ALGOL.

Dec.	14	23
	17	19

ALGOL CONT.

1896.

	d	h
Dec.	20	16
	23	13

R CANIS MAJ.

Dec.	5	13
	6	16
	7	19
	8	22
	14	15
	15	18
	16	21
	18	1

R CANIS CONT.

1896.

	d	h
Dec.	22	14
	23	17
	24	20
	25	23
	31	16

S CANCRI.

Dec.	5	16
	24	15

δ LIBRAE.

Dec.	26	0

U CORONAE

1896.

	d	h
Dec.	30	0

W DELPHINI.

Dec.	2	5
	7	1
	11	20
	16	15
	21	11
	26	6
	31	1

Maxima and Minima of Long Period Variables.

MAXIMA.

1897 January.

110	S	Tucanæ	18:
513	R	Piscium	12
1577	R	Tauri	12
1623	T	Camelopard	16
1635	R	Reticuli	22
2539	R	Canis min.	10
2780	T	Geminorum	19
2815	U	Geminorum	2:
3418	R	Carinae	9
3425	X	Hydræ	31
4557	S	Ursæ Maj.	15
4596	U	Virginis	31
5494	S	Libræ	27
5593	W	Libræ	5
5776	X	Scorpii	1

MAXIMA CONT.

1897 January.

5830	R	Scorpii	13
6050	RS	Scorpii	1:
6512	T	Herculis	31
6894	S	Lyræ	25:
6921	S	Sagittarii	14
7085	RT	Cygni	28
7404	R	Microscopii	2
7455	U	Capricorni	6
7482	U	Pavonis	29:
7659	T	Capricorni	28
8153	R	Lacertæ	29
8324	V	Cassiopeæ	16
8591	V	Cephei	1
8622	W	Ceti	25

MINIMA.

1897 January.

112	R	Andromedæ	17:
782	R	Arietis	26
1771	R	Leporis	11
2676	U	Monocerotis	15
3994	S	Leonis	12:
4847	S	Virginis	2:
4896	T	Centauri	25
5194	V	Bootis	5
6905	R	Sagittarii	26
7192	Z	Cygni	2:
7257	R	Sagittæ	31
7560	R	Vulpeculæ	26

The ephemeris of long period stars was computed directly from the elements given in Chandler's Third Catalogue. The arrangement, according to the Right Ascension, instead of in the order of time, is that recommended by Dr. Chandler and found most convenient for use. A colon after the date signifies doubt.

The date for the Algol stars are taken as usual from Hartwig and Pickering.

COMET NOTES.

Brooks' Periodic Comet 1889 V—This comet is still visible, although very faint.

In *Astronomical Journal*, No. 385, Dr. S. C. Chandler questions whether the comet seen this year, is as it has been assumed to be, the component *A* of the four

portions of the comet seen in 1889. "It appears to me that such identity has yet to be demonstrated; that it is indeed quite problematical, in view of the great alternations in the size and brightness of the four components seen in 1889. In support of this view I need only recall the fact that during the latter part of August and the early part of September of that year, the fragment *C* was actually brighter than *A*. Indeed, at one time even *B*, according to Barnard, had a brighter nucleus than *C*, and a smaller and less diffused coma. There is danger then that, unless another component is discerned at this appearance, the theory of the comet will be left in an imperfect condition,—resting as it does on the unstable hypothesis referred to. The case is analogous to that of Biela's comet, where the classical discussion by Hubbard left the identity of the components seen in 1846 and 1852 an unsettled question." Dr. Chandler gives an ephemeris for the component *C* from which it appears that *C* should be about 12ˢ.5 following and 1′.4 north of *A*. In our observations at Northfield nothing comet-like has been visible within the distance assigned from *A*. Special search was made at greater distances on Oct. 12, with the result of finding a faint object 2ᵐ 25ˢ following and 3′ north. This, however, turned out to be nebula N.G.C. 7246.

In *Astronomical Journal*, No. 386, Dr. Chandler corrects his ephemeris of the fragment *C* of Brooks' periodic comet and finds that its position relative to *A* "varies quite uniformly from 2ᵐ 34ˢ following and 16′.8 north on Oct. 3, to 2ᵐ 2ˢ following and 15′.0 north on Oct. 31.

"From the magnitude of these differences it is manifest that the remarks about the identity of the fragment hitherto observed during the present appearance lose their force."

Ephemeris of Comet *c* 1896 (Brooks 1889 V).

[From *Astronomical Journal*, No. 386, by Charles Lane Poor.]

Gr. M. T.	R. A. h m s	Decl. ° ′ ″	log Δ	Brightness.
Nov. 4.5	22 26 24	— 12 20 13	0.1386	1.2
6.5	28 30	— 11 58 0		
8.5	30 40	— 11 35 28	0.1504	1.2
10.5	32 57	— 11 12 37		
12.5	35 17	— 10 49 21	0.1622	1.1
14.5	37 43	— 10 25 43		
16.5	40 13	— 10 1 50	0.1740	1.1
18.5	42 48	— 9 37 30		
20.5	45 27	— 9 12 59	0.1857	1.0
22.5	48 8	— 8 48 7		
24.5	50 56	— 8 23 0	0.1974	1.0
26.5	53 46	— 7 57 30		
28.5	56 40	— 7 31 55	0.2090	0.9
30.5	22 59 38	— 7 6 4		

Giacobini's Comet *d* 1896.—No observations have reached us bearing dates later than Sept. 11. It is to be hoped that the comet has not escaped all the observers since that date. We have looked for it several times and failed to see it. The preliminary elements disagree very badly and the errors of the ephemerides probably account for the failure to find the comet. It seems probable that the orbit is decidedly elliptic so that a parabolic path would represent the comet's movement for only a few days.

Elliptic Elements of Comet *d*, 1896 (Giacobini).—In *Astronomical*

Journal, No. 386, Rev. G. M. Searle gives the following elliptic elements of Giacobini's comet, obtained from observations dated Sept. 5, 9 and 28:

$$\begin{aligned} T &= \text{Nov. } 2.5242. \\ \Omega &= 196^\circ\ 14'\ 30'' \\ \omega &= 144\ \ 8\ 17 \\ i &= 10\ 58\ 13 \\ \varphi &= 28\ 43\ 52 \\ \log a &= 0.428573 \\ \text{Period} &= 1605 \text{ days} \end{aligned}$$

Of the ephemeris calculated from these elements we copy only the last three dates, since the others are already past.

EPHEMERIS OF COMET *d* 1896.

Gr. M. T.	R. A. h m s	Decl. ° ′	log Δ	Brightness.
Oct. 27.5	19 30 20	− 13 40.7	0.0877	0.88
29.5	19 36 52	− 13 43.7	0.0906	
31.5	19 43 26	− 13 45.7	0.0935	0.85

Sperra's Comet *e*, 1896—This comet is exceedingly faint. Our last observation was on Sept. 28. On October 7 and 12 we failed to see it.

GENERAL NOTES.

Three fine plate illustrations intended for this issue were spoiled in making. There was not time to secure them anew, so much useful matter is necessarily deferred.

We have just received notice from Percival Lowell, Flagstaff, Arizona, that more new and important matter concerning Mars will be forwarded to POPULAR ASTRONOMY soon. It will doubtless be ready for the December issue.

Discovery of New Double Stars at the Lowell Observatory.—It is reported from Flagstaff that the work on Double Stars undertaken by Dr. See is already bearing fruit. Nothing could be of greater interest than the discovery that θ Scorpii, the large red star in the lower bend of the Scorpion's tail, has a companion so close that the physical nature of the system is evident. We understand that the companion is a greenish star of the 13th magnitude, distant 7″ and situated in position angle 320°. The new system in the Scorpion thus resembles Antares, except that the object discovered by Mitchell is much easier than that found by See. θ Scorpii will henceforth constitute an elegant test object for the power of telescopes.

Among the other objects just discovered we notice a third component to β Delphini. This star is said to be of 13th magnitude, purple in color, and situated in angle 113°, at a distance of 6″. It is thus very close to the rapid binary system discovered by Burnham in 1874, which has now completed almost a whole revolution, and is one of the most interesting objects in the heavens. The new companion will almost certainly be connected with the binary pair, and thus constitute a Ternary system, probably in comparatively rapid motion.

Though Dr. See speaks as if the discoveries were to be credited wholly to the splendid new 24-inch, of which our readers will have an account next month, we are inclined to think that the outsider will conclude that the man at the eye-end is a factor of some importance in getting such interesting results.

A New Spectroscopic Binary μ^1 Scorpii.—From an examination of the Draper Memorial photographs Professor Solon I. Bailey has found that the star μ^1 Scorpii is a spectroscopic binary. This star is $-37^\circ\ 11033 =$ S. M. P. 5794. Its approximate position for 1900 is in R. A. $16^h\ 45^m.1$, Decl. $-37^\circ\ 53'$, and its photometric magnitude is 3.26. Its spectrum is of the first type and contains the additional lines characteristic of the Orion stars. It, therefore, belongs to Class B according to the notation of the Draper Catalogue. The star μ^2 Scorpii follows about 28^s and is $1'.7$ north, and its photometric magnitude is 3.74. The spectra of both stars, therefore, appear side by side in the photographic plates. In some they are scarcely distinguishable, while in others the lines of the first star are broad and hazy, some of the faint lines appearing distinctly double. The lines in the spectrum of the second star are always single and well defined. One of the components of the binary is fainter than the other, so that the lines of its spectrum are sometimes of greater, and sometimes of shorter, wavelength than those of the brighter component. The difference in intensity also seems to change as if due to a variation in the light of one of the components.

An examination of the plates already sent to Cambridge shows that the spectrum of this star was photographed on October 2, 1892, July 20, 1894, and July 31, 1894. On the first of these plates the lines are single, on the second they are wide and hazy, and on the third they are double. When Mrs. Fleming examined these plates in October, 1894, she recorded on the second of them "Lines double?" and on the third of them "Lines double." They were laid aside for further examination but were overlooked.

The changes are so rapid that they are perceptible in successives plates having exposures of one hour. From a discussion of 52 photographs Professor Bailey has derived a period of 35 hours and a nearly circular orbit.

An independent discussion made here, shows that all the observations, including those of the early photographs, may be represented by the formula, J. D. 2412374.52 + 1.4462 E. which gives an average period of $34^h\ 42^m.5$ with an uncertainty of less than a tenth of a minute. Ten observed times when the lines were single are represented with an average deviation of 38 minutes each. The maximum deviation is less than an hour. Further observations will, however, be required to make sure that no other assumption is possible for the total number of epochs since 1892. In 19 photographs the lines of the fainter component were found to have greater, and in 14, shorter, wavelengths than those of the brighter component. This was confirmed later, in each case, by the formula.

Only two stars of this class are already known. The first, ζ Ursæ Majoris, was found by the writer in 1889. The period appears to be about 52 days but it is irregular, perhaps owing to the presence of a third body, and the time during which the lines are widely separated is short. The second star β Aurigæ was found later in the same year by Miss A. C. Maury. The changes appear to be perfectly regular with a period of a little less than 4 days.

EDWARD C. PICKERING.

Harvard College Observatory, Circular No. 11, August 31, 1896.

Mr. DeLisle Stewart, a recent graduate of the post course of study in

mathematics and astronomy at Carleton College and now regular observer at the Harvard College Observatory in Arequipa, Peru, writes of his present work, under date of Sept. 15th, as follows:

"My own work amounts to seven or eight hours a day. About five hours at night and photographic work in the dark-room during the day. A large part of our time is employed in taking photographs to be sent to Harvard College Observatory at Cambridge, Mass. Securing photographs of spectra of stars with the objective prism has been particularly interesting to me, especially some of the late work with three prisms attached to the 13-inch telescope. The spectra on the plates are about four or five inches long and show a great number of lines. Within the last few months Professor S. I. Bailey has discovered that μ Scorpii is a spectroscopic binary. The revolutionary period is very regular, and is only 35 hours.

Professor W. Upton, of Ladd Observatory, Providence, R. I., is also here at work. He is now putting the transit instrument in order to undertake latitude and longitude observations soon."

The Variable Star Mira, *o* Ceti.—This star either did not go so low at the last minimum as in 1895, or it has already begun to brighten. On the night of October 12 it was three or four times as bright as the companion star (*T*), and was estimated to be equal to *N* of Mr. Parkhurst's list of comparison stars. (See POPULAR ASTRONOMY, Dec., 1895, p. 166). At the minimum in 1895 *Mira* was but slightly, if at all, brighter than *T*. The color of *Mira* is now intensely red.

A later observation, Oct. 19, seems to verify the supposition that *Mira* is increasing in brightness. On that evening the variable was decidedly brighter than the star *N* and fainter than *H*, about midway between the two in brightness. This would make the magnitude 8.0. The comparisons with other stars do not agree as closely as could be desired and seem to indicate that the star *S* is brighter than the magnitude 8.95 given by Mr. Parkhurst.

A. G. Sivaslian, Professor of mathematics and astronomy in Anatolia College, Marsovan, Turkey, who was the first to complete a post course of study in mathematics and astronomy at Carleton College, writes under date of October 1, that there are about 120 students in attendance at the college, and that the school work is going on favorably. Mr. Sivaslian is instructing a class in astronomy in the college and using Young's Astronomy as a text-book. He is also planning to mount some instruments for practical work in astronomical lines.

Miss Flora E. Harpham formerly a student in special post studies at Goodsell Observatory, has been recently appointed to the position of computer at the Observatory of Columbia University in the city of New York. Congratulations are in order since Miss Harpham is the first lady to be appointed to such a position in the above named Observatory.

"The Observer" of Portland, Conn., which was recently enlarged and so much improved, has been suspended, if we are rightly informed. This is to be regretted because it certainly had made a very creditable appearance during the last few months.

Leander McCormick Observatory of the University of Virginia, Professor Ormond Stone, Director, has an equatorial telescope whose lens is 26-inches

clear aperture. Professor Stone for some time has been at work on the motions of the satellites of Saturn, special attention being given to the fainter satellites which can only be observed by the larger telescopes. Mimas and Enceladus are faint in large instruments, but a good knowledge of the motions of these small bodies are useful in determining the mass of Saturn's rings. Hyperion is extremely faint and its motion is greatly affected by the attraction of the great satellite Titan. Mathematicians are much interested in the orbits of these last two named satellites because of the interesting problems made by their mutual attractions. Professor Stone is doing an important piece of work and the results of his investigations will be greatly appreciated.

Observations of N and S Scorpii.—These noted variables, in the same field of view as 80 Messier, were observed with a four-inch telescope during their recent maxima, which occurred in June last according to the "Companion to the Observatory." Unlike the usual variable, neither are in the least degree red tinted, but may be classed as of the faintest yellow. At maximum they are of about 10th magnitude, and though their periods are different, on this occasion they glimmered out within the same few weeks, and according to Webb are 3′ apart. However, they seemed much nearer. A star of 9th magnitude marked *d* in "Smyth's Cycle of Celestial Objects" was chiefly used for comparison, but neither attained even to that faint lustre.

N Scorpii, Period 223 Days.

May 5th, 1896.....After some cloudy weeks N was visible as a star of 10th magnitude. It was observed frequently during May, but no increase was detected.
June 2d, 1896.....This was the day of predicted maximum but its light was not greater than in May. It was much brighter than S just visible.
June 6th, 1896.....Same brightness as S.
June 11th, 1896.....Less bright than S.
June 15th, 1896.....Nearly invisible.
June 18th, 1896.....Invisible.

S Scorpii, Period 176 Days.

May 31st, 1896.....Not visible.
June 2d, 1896.....Faintly visible.
June 5th, 1896.....Nearly as bright as N.
June 6th, 1896.....Of the same brightness as N.
June 9th, 1896.....It seems somewhat brighter. This is the day of predicted maximum.
June 11th, 1896.....It is brighter than N.
June 18th, 1896.....Compared with the neighboring star *d*, it has not decreased
July 9th, 1896.....Barely discernible through clouds.
July 10th, 1896.....It is fainter.
July 12th, 1896.....It was invisible after this date.

ROSE O'HALLORAN.

At the setting of the Sun on Sept. 20th, chancing to look out of the window to watch its sinking behind a spur of the Sierra Madres, my eye instantly caught a very bright object, by estimation about a degree above the Sun's upper limb. At that time about one-third of the Sun had already set. Repairing quickly to the veranda of Echo Mountain House, from whose windows I had detected this stranger, I saw it with greater distinctness, and seizing an opera-glass, my suspicion that it was a comet was confirmed, and also to my amazement, the glass revealed a much fainter one, the three bodies forming a right angle triangle. A second and much finer field glass, a very excellent one, was procured which showed them in like manner as the first. About a dozen of the guests of the

hotel saw both objects precisely as they appeared to me. The Sun's light, by smoke near the horizon (for weeks huge fires have burned on the mountain north of us) was so weakened that the eye could look at it without discomfort, a condition which must have diminished the normal light of the comet also.

The objects simultaneously set behind the mountain about four minutes after the disappearance of the upper limb of the Sun. The brighter of the two must have been several times more brilliant than Venus which was not visible for some time after the Sun sank and then only as a faint point of light.

Now, if the bright one were a comet, and of course it was, then the other, to be a companion of it was much out of the proper direction from the Sun, and so the question arises, were they both comets?

The next night arranging for it, with the great glass pointed to the place, I swept with the 4½-inch comet-seeker from its station on the roof of dark room close by, but saw nothing until half of the Sun had set when with difficulty I discerned one of the hunted bodies. If this which I now saw were the most brilliant one, its brightness must have diminished enormously as it was no more conspicuous with the telescope than it had appeared with the opera-glass on the night previous. After gazing at it for a few seconds, I rushed to the 16-inch telescope for a view, if possible, but the eyepiece being beyond my reach, I hastily returned to the smaller glass only to find that both Sun and comet were hopelessly gone behind the mountain. I have not seen them since. It was among the strangest of my experiences.

I am greatly wondering why the brighter body, so conspicuous as it was was not observed elsewhere.

LEWIS SWIFT.

Lowe Observatory, Echo Mt., Cal.,
October 11, 1896.

Notes of an Aurora seen August 6th, 1896, at Lake Placid, New York.—It was my privilege this summer on the evening of August 6th, to see a most remarkable auroral display, which must have been confined to the region of the Adirondacks, as no account of it has fallen under my eye in any newspaper or periodical. On the following morning I made a few notes of the unusual appearances, and from these will try to give as intelligible an account as I may.

The display began about eight o'clock, with ordinary appearances of short streamers rising from behind the mountains on the northern horizon. Within half an hour, very suddenly, a luminously bright band or streamer started from behind a small, dark cloud about fifteen degrees above the east northeast horizon, and in a few moments had not only shot to the zenith, but gone completely over to the western horizon, forming an entire, brilliant arch directly over head. It displayed all the usual characteristics of auroral light, the stars being plainly visible through it, and was of almost uniform brightness, much brighter than the Milky Way, which it crossed at nearly right angles.

Then there began a fine rippling or flowing of light in the band, starting always at the eastern end and reaching slightly past the zenith, which resembled the rapid drifting of a light cloud scud directly over one's head.

The band was from one and a half to three degrees broad, when it first appeared just embracing the four stars forming the diamond in the Dolphin at the eastern end, and descending toward the western horizon exactly between the terminal star in the tail of the Great Bear (η Ursæ Majoris) and Arcturus (α Boötis).

Then the arch as a whole, bodily drifted toward the south and when it faded

a half hour later, was considerably to the south of Altair (α Aquilæ) and Arcturus (α Boötis). At times the band appeared as if twisted spirally in strands, and just before fading away, it broke up into great, pendent fringes.

When the arch vanished, the northern display brightened, but presented no unusual features. The impressive sight was that great arch of light, without sound or effort, suddenly sprung from eastern to western horizon, and, for half an hour, softly shining over our heads. M. E. HUTTON.

New Brunswick, New Jersey.

Gifts to Lick Observatory.—Miss Caroline W. Bruce, of New York City, has given to Lick Observatory a sum of money to procure a large comet-seeker, and to provide photometers for visual use with the thirty-six-inch equatorial.

Mr. Walter W. Law, of Scarboro'-on-Hudson, has likewise made a liberal gift towards providing for the publication of the Observatory Atlas of the Moon mentioned in these publications, volume VIII, page 187. (*Publications of the Astronomical Society of the Pacific, No. 51.*)

Young's Lessons in Astronomy, New Edition, (1895).—We are in receipt of the new edition of Young's Lessons in Astronomy. The progress in Astronomy has been so great since the first edition of this book was published (only a few years ago) that the author has deemed it best to revise it. We have looked through the new book with much interest to see what changes have been made to bring it to date in all particulars and we find the changes are many and some of them important, chiefly in the way of addition to the old text, the corrections in previous statements being very few. The following are a few of the many: Page 2 about astrology as a "baseless delusion," and the stars revealed by the telescope not seen by the naked eye, and the possibility of thousands of dark bodies whose presence is manifested by affecting the motions of their neighbors. Pages 8 and 20, minor changes. The Uranography covering about 20 pages we would scarcely expect to be changed. Page 73 has an important new note under the head of, *Shifting of the Earth's Axis*, as determined by Dr. C. S. Chandler through a study of the variations in the latitudes and the longitudes of observatories. This matter has been presented fully in recent numbers of this publication notably in the excellent article by Eric Doolittle, (see November number 1895). Page 76 contains a note on work by Boys of England, concerning the density of the Earth; also, on work now in progress in Berlin. Page 118 speaks of the facular projection at the edge of the solar disc, "the spectrum of which shows bright lines of calcium vapor which makes it uncertain whether they may not be clouds of that substance floating high above the photosphere," instead of being part of the photospheric matter. It is also added on this page that there is considerable probability that "the principal element of the photosphere is *carbon* though this can not yet be regarded as proved." These are important additions.

Under the head, *Nature of Sun Spots*, pages 121, 122, 123, regarding the temperature of the nucleus of a sun spot the motion of photospheric and other matter in the vicinity of spots, the level of the spots, and Spoerer's facts in regard to the curious manifestations in the north and south belts 30° distant from the equator at the time of spot maximum are additions to the old text which students in this line of study will readily notice. There is an instructive new paragraph on the elements now known to exist in the Sun on page 120. They are all metals but one, carbon. The number of comparisons by which each element has been determined is also given in the table. The articles on the prominences and their

photography are very interesting and largely new, in order to present what has been recently learned about argon and helium. On page 160 we notice one error. The number of satellites for Jupiter is given as four. On page 199 the righn number is given.

Speaking of the flattening of the poles of the planet Mars, page 184, the value of about 1/200 is given, larger values are now known to be erroneous. The recent discoveries pertaining to Mars, including the "canals" and their gemination, nature of the polar caps, and the surface markings generally are commented on fully on pages 185, 186 and 187. The different views held at the present about these phenomena, including the idea of habitability, are stated fairly and justly with the author's usual caution. In the chapter on the Asteroids we have a needed addition on page 191 relating to the number of the asteroids and how they are discovered by photography. Other changes following in later chapters are as many as those already indicated, which brings the book to date in, as far as we have noticed, a very faithful revision. Teachers already generally know that this text-book is *the one* elementary text-book that covers the subject fully and thoroughly. This new edition will be very acceptable everywhere.

The Weather in August, 1896, at Lick Observatory.—A rain-storm with a precipitation of nearly three-tenths of an inch on the night of August 29-30 came as a fitting climax to a most unusual August. Past experience has led to the expectation of the best observing weather of the year during this month; and a few of the earlier nights seemed to justify this expectation, the "seeing" leaving nothing to be desired. But since the tenth there have been nine cloudy nights; and an examination of the notebooks of the observers shows that on the nights that were clear enough for work, the "seeing" was rated three or less (five representing the best conditions) on twelve nights. On only two nights during the present lunation were the atmospheric conditions good enough to allow the use of the thirty-six inch refractor for lunar photography. The lower levels of the atmosphere have been filled with haze and smoke due, in great part to immense forest fires in Washington and British Columbia.—(*Pub. Astronomical Society of the Pacific, No. 52.*

Discovery of Six New Asteroids.—In September Professor Max Wolf, at Heidelberg discovered six new asteroids. One was found upon a photographic plate taken Sept. 3, the other five upon a plate of Sept. 7. Their positions were as follows:

	Mag.	Heidelberg M. T.			R. A.			Decl.		Daily Motion in R. A.	Daily Motion in Decl.
			h	m	h	m	s	°	′	s	′
CM	12	Sept. 3	10	49	22	45	28	+2	32	−40	− 4
CV	12	7	10	39	22	49	52	+5	30	−52	− 5
CW	11	"	"	"	23	9	0	+1	19	−56	− 6
CX	11	"	"	"	23	13	40	−0	23	−52	− 5
CY	12 5	"	"	"	22	44	28	+2	4	−40	− 5
CZ	12.5	"	"	"	23	2	28	+0	25	−40	−10

The Death of William C. Winlock, Superintendent of exchanges in the Smithsonian Institution at Washington, D. C., is announced. It occurred September 20, at the early age of 37. Mr. Winlock was a son of Professor Winlock, a former director of Harvard College Observatory. We hope to present a biographical sketch later.

Mr. Lumsden's Suggestions for Amateur Lunar Work.—We have recently received a very useful letter from G. E. Lumsden, of Toronto, in regard to the work of amateurs and the help that POPULAR ASTRONOMY is, and may be, to them. We take the liberty of making some extracts from his letter, in order that others may understand the methods of work proposed. He says:

"I have often thought that if your readers could get down to actual practical work, it would be well. Now, for instance, if in your admirable articles on the Moon, my special subject, you were to call for drawings of certain features you might awaken a wide-spread interest that would answer a good purpose. During the last two lunations, I have given all my time to the Sea of Nectar, and especially to Mädler in the western and to Aristarchus, Herodotus and Schroeter's Valley in the eastern hemisphere. Many other objects I have studied and drawn, but these are interesting me just now. Several of our members have also selected objects. The drawings are to be exchanged and compared. Mädler may not be much of an object as seen on a map or photograph, but I have been amazed at the work that can be put upon it and its immediate neighborhood during a lunation. I have, or have access to, most of the works on the Moon, but I believe I have made out some details that I do not find mentioned. Personally, I feel that Astronomy is made too little attractive by the everlasting importance given by all our serials to such difficult and unsatisfying work as splitting double-stars, etc., looking up nebulae and the like, while the most splendid object in the heavens, not even excepting the Sun, viz., the Moon, is practically neglected. If I had put on the Moon the years I have wasted in trying to pick up all the doubles in Webb, etc., I would have had ten times the advantage from my work. I am not depreciating, I hope unduly, the great value of the work to which I have, perhaps, referred too lightly, but my point is that we should have very many more amateur observers if we made more of the Moon than we have in an era when objects requiring high priced apparatus are made the texts for study and examination. As but few can afford such appararus, they neglect their opportunities, little knowing that with ordinary assistance they would de delighted and profited with lunar work.

It seems to me that much can be done that remains undone."

In another part of his letter Mr. Lumsden proposes a plan to stimulate observation and drawing in regard to certain objects on the lunar surface in order to secure more thorough knowledge of them. In regard to his point he says:

"To show that I am in earnest, I am willing, if you approve, to donate three copies of Elger's Moon for the three best drawings of the Sea of Nectar and of Mädler, and of Aristarchus, Herodotus which shall be sent in to you as umpire, before a certain date. Though most excellent, the books would not be given as a reward for, but rather as an incentive to, work to be done. You might specify conditions."

These are excellent suggestions and we hope to be of assistance in carrying them out in the near future. In order to do so we will have to make some changes in the present plan of our publication which will take some little time to do. More will be said of this soon.

Astronomical and Physical Society of Toronto.—The matter of renewals of subscriptions for common publications in the Astronomical and Physical Society of Toronto for this year was put into the hands of a special committee for consideration. In regard to this publication the committee reported as follows:

"Your Committee has pleasure in bearing testimony to the general excellence of POPULAR ASTRONOMY and to the efforts which have been made by Professor Payne and his staff to maintain the magazine at the high standard promised at its inception and desires to express the hope that the anticipations of the publishers will be fully realized.

"Your Committee would, therefore, recommend the renewal of the Society's subscription, but, in doing so, would ask permission to suggest for the consideration of the Society the advisability of inviting Professor Payne's attention to the propriety of devoting a larger portion of POPULAR ASTRONOMY to the requirements of amateurs who have not yet attained the ability to appreciate some of the articles published, as it would appear, in the interest of astronomical students whose mathematical qualifications and whose practical experience justify them in calling for, in the magazines to which they subscribe, papers of a high order, papers, which, however, are too abstruse and too difficult for most amateur observers and, therefore, not likely to strengthen POPULAR ASTRONOMY among that class of students for which it is professedly published and from which it would most probably draw its largest subscription list. Your Committee would make any specific suggestions with great diffidence but if it were to venture upon one it would be that the editors give up, at least, one-third of the magazine to subjects and matters of especial interest to young observers and make it a common ground upon which amateurs, by means of letters or notes, could meet, somewhat after that adopted by the editor of *The English Mechanic.*"

These are also most pertinent suggestions and they ought to be embodied in our plan of work. If we can possibly see our way clear for financial support to make the changes needed and to give the additional space necessary for the lunar work as suggestively outlined above, we shall consider it favorably most assuredly.

Errata.—Page 213, $\frac{\varphi + s}{2}$ and $\frac{\varphi - s}{2}$ should be $\frac{\varphi + \delta}{2}$ and $\frac{\varphi - \delta}{2}$. Also "errror" for error, and "clamororrd" for clamored.

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